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PREFACE

This report represents a compilation of summary progress reports of saline-alkali research and control projects, funded wholly or partially by the Department of State Lands' Saline-Alkali Program, during the fiscal year ending June 30, 1975.

The 1974 Legislature recognized saline seep as one of Montana's most urgent conservation problems. Acting in accordance with the recommendations of the 1973 Governor's Emergency Committee on Saline Seep, the Legislature appropriated $10,000 for F/Y 74 and $255,000 for F/Y 75 to be used for the development and implementation of a saline-alkali research and control program. Governor Judge charged the Department of State Lands with the responsibility of funding and coordinating saline-alkali control projects and activities. The Governor also appointed a seven-member Saline Alkali Advisory Council in April 1974 to assist the Department in these duties.

The Department and the Advisory Council determined that F/Y 75 research and control activities should fall into the following areas:

a. Research into the solutions of both dryland and irrigation salinity.

b. Measurement of the magnitude, nature and location of the problem.

c. Development of technology for the measurement of the problem.

d. Determination of the effects of the saline-alkali problem on water quality.

The projects undertaken during FY 75 have begun to set the stage for future direction of attack on the saline-alkali problem in Montana. Most projects under the Saline-Alkali Program have been continued into F/Y 76 and will require additional time to fully develop conclusions and recommendations. Some studies, however, have been completed or are being continued under other sources of funding. Following is a list of agencies that conducted projects during F/Y 75 and their respective funding:

a.	Montana Bureau of Mines and Geology.........	$43,800 plus $15,000 for drilling expenses
b.	University of Montana.......................	$ 8,500
c.	Department of Health and Environmental Sciences....................................	$19,494

d.	USDA Agricultural Research Service	$20,000
e.	Paradise Irrigation District	$15,000
f.	Soil and Water Conservation Districts of Montana, Inc. (Supplements a larger grant from the Old West Regional Commission)	$ 7,000
g.	Ecological Consulting Service	$ 9,398
h.	Montana State University	
	Montana Agricultural Experiment Station	$38,900
	Montana Cooperative Extension Service	$38,900

The State's role through the Saline-Alkali Program is to determine methods of controlling the saline-alkali problem and encourage their earliest possible implementation. Once feasible practices for control and prevention of the problem are developed and information made available to producers, the State's involvement will be de-emphasized. The long range solution to the problem lies with individual farm and ranch operators upon whom greater responsibility for corrective action will be placed.

We wish to express our deep gratitude to the members of the 1974-75 Montana Saline-Alkali Advisory Council for their support and assistance in developing a sound saline-alkali program. The members of the Advisory Council were Senator Gordon McOmber, Fairfield; Gordon Bollinger, Glasgow; Tom Clemow, Jackson; Robert Anderson, Fort Benton; Norris Hanford, Fort Benton; Representative John Murphy, Stanford; and L. Ronald Bokma, Conrad.

Finally, special acknowledgement must be given to the late Robert S. Duncan for his great contributions in establishing the saline-alkali program.

Les Pederson
Roger Veseth
Saline-Alkali Program
Montana Department of State Lands

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Saline-Seep Report to
Department of State Lands
Helena, Montana

July 31, 1975

Project: Origin, development, and regional extent of salinity problems in Montana - hydrogeological aspects.

Principal Investigator: Marvin R. Miller, Chief, Hydrology Division
Montana Bureau of Mines and Geology
Butte, Montana 59701

Other Personnel: John L. Sonderegger, David J. Smith, Robert N. Bergantino, Fred A. Schmidt, Wesley M. Bermel

Origin, Development, and Regional Extent of Salinity Problems in Montana - Hydrogeological Aspects (Progress Report)

Project Objectives

The purpose and overall objective of the project is to examine in detail the origin and development of saline seeps in order to reduce or at least control the spread of salt accumulation and the deterioration of surface-water and shallow ground-water resources of the region.

Before corrective measures can be undertaken, the hydrogeological system of selected representative areas in Montana must be understood. For such understanding, information must be obtained by the following procedure:

1. Drill test holes in each of the selected areas to determine depth of bedrock, nature of material, thickness of glacial till, if present, and depth to water table.
2. Examine and characterize several areas adjacent to reservoirs and nearby coulees where loss of livestock has been reported.
3. Utilize geophysical techniques to supplement test-hole data to help characterize recharge and discharge areas.
4. Monitor selected wells to record water-level fluctuations with time, to establish direction of ground-water flow, and to delineate recharge and discharge areas.

5. Instrument one or more small watersheds in each of several major areas to obtain a complete and accurate water budget. If possible, at least one of the watersheds would be located in a native-sod area.

6. Conduct aquifer tests to determine permeability, transmissibility, and effective porosity of the medium.

7. Conduct infiltration tests to ascertain the rate and quantity of water moving downward through the soil profile.

8. Collect and analyze samples of water, salt, soil, and rock to evaluate the salinization potential in the northern plains.

9. Assess and quantify the potential regional extent of the problem.

10. Cooperate and coordinate closely with other investigators to ensure that the overall objectives of the program are acheived.

11. Analyze, organize, and evaluate data for a report.

Progress through June 30, 1974

During the summer of 1974, several areas in northern and eastern Montana were selected for research. Other members of the research teams, principally Jim Krall, Steve Custer, Paul Brown, Hayden Ferguson, and Don Ryerson, were consulted in order to coordinate wherever possible with their plans and objectives. Local SCS District conservationists and county extension agents in each area were very helpful in selecting and lining up the test areas.

In October the drilling program was begun. The Mobil 50 auger drill of the Montana Highway Department was used, with assistance in the Rapelje and Denton areas from the Soil Conservation Service drill rig. The weather remained remarkably good, and the drilling continued to the end of December. During the period, 184 test holes were drilled and logged on 17 different sites; footage totaled 7,040 feet. All but two holes were cased, which required the use of 6,970 feet of casing. Most holes were cased with 3-inch pipe, but selected wells were cased with 4-inch casing. All the holes were flushed and gravel packed. Throughout the drilling program Steve Custer assisted with collecting the samples and logging the holes. Approximately 1,300 samples were collected from 72 holes, 10 of which were cored.

During the winter and spring the following have been accomplished:

1. All the sites have been visited five to ten times, and water-level and specific conductivity measurements for each test hole recorded.

2. Ten Type F water level recorders have been installed on the Hoagland, Brickley, Hanford, Bokma, and Newby test sites, and one type A35 recorder has been maintained on Nine Mile Coulee near Fort Benton.

3. Gamma, resistivity, and spontaneous potential logs were run on selected test holes for added lithologic control.

4. Conductivity profiles utilizing the standard wenner configuration (4-probe technique) were completed on the Hoagland, Brinkley, Barber, Hanford, Bramlette, Wharran, and Huffman sites. Both fixed and expanding spacings were used.

5. To ascertain regional water-quality trends, specific-conductivity measurements of selected wells, springs, streams, and reservoirs have been taken in Stillwater, Judith Basin, Liberty, and Hill Counties. The inventory will be continued and expanded during the next fiscal year. Additional funding obtained

from the Old West Regional Commission will supplement this program.

6. Based on available water-well log information on file a generalized glacial-till-thickness map of northern Montana has been completed. Additional field checking of selected areas will be required.

7. Preliminary leachate studies of the soil profile have been conducted to determine the water-soluble salt load within the surficial material. A relatively inexpensive method of extracting the water-soluble load from augered samples has been found.

8. Precipitation records have been tabulated for each research site based on published information at nearby weather stations.

9. Numerous talks and lectures related to the saline-seep program have been given during the year, and the Bureau of Mines and Geology personnel participated in several meetings, field trips, and workshops last year.

A generalized description and location of each test site follows:

Site 1. Rapelje region - Hoagland area
County: Stillwater Owner: Bill Hoagland
Location: T. 4 N., R. 21 E., sec. 32
No. of Holes Drilled: 8 (all cased, flushed, and gravel packed)
Other Data: Water levels taken; two water-level recorders installed; SC, Eh, and pH measured; conductivity profiles run
Topography: Internally drained basin (unglaciated area)
Surficial Material: Colluvium (derived from Eagle and Colorado Formations)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Principally alternate crop-fallow area, some alfalfa
Remarks: This site had previously been sleected by Hayden Ferguson and Jim Krall. See figures 1-1, 1-2, and 1-3.

Site 2. Rapelje region - Brickley area
County: Stillwater Owners: Brickley, Holland, and Doley
Location: T. 4 N., R. 20 E., sec. 35, 36
T. 3 N., R. 20 E., sec. 12
No. of Holes Drilled: 11 (all cased, flushed, and gravel packed)
Other Data: Water levels taken; two water-level recorders installed; SC and pH measured; conductivity and seismic-refraction profiles run
Topography: Internally drained basin (unglaciated area)
Surficial Material: Colluvium (derived from Eagle and Colorado Formations)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Native sod and alternate crop-fallow area
Remarks: This site should be excellent for comparing cropped versus sod systems. Sod area was very dry relative to nearby cropped area. See figures 1-1, 2-1, and 2-2.

Site 3. Rapelje region - Schneidt area
County: Stillwater Owner: Dale Schneidt
Location: T. 1 N., R. 22 E., sec. 11 (near Molt)
No. of Holes Drilled: 6 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken
Topography: Internally drained basin (unglaciated area)
Surficial Material: Colluvium (derived from Judith River Formation)
Bedrock Formation: Judith River Formation (Cretaceous)
Vegetation: Previously continually cropped but going back to alternate crop-fallow because of poor yield
Remarks: Water is moving downslope in permeable units of the Judith River Formation. See figures 1-1 and 3-1.

Site 4. Denton region - Melton area

County: Fergus Owner: Dori Melton
Location: T. 17 N., R. 4 E., sec. 6
No. of Holes Drilled Previously: 8
Other Data: Old holes surveyed, water-level and specific-conductance measurements taken
Topography: Gently sloping gravel-capped terrace (unglaciated area)
Surficial Material: Fluvial terrace deposits - very permeable
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Alfalfa on seep area and alternate crop-fallow on surrounding areas
Remarks: Holes were drilled several years ago by SCS but no water-level measurements are available. Several additional holes should be drilled in future to supplement existing well network. Hydrogeologically, the area should be very similar to Brinkman areas (site 5). See figure 5-1.

Site 5. Denton region - Brinkman area

County: Fergus Owner: Ron Brinkman
Location: T. 19 N., R. 13 E., sec. 29 (near Coffee Creek)
No. of Holes Drilled: 21 (all cased, flushed, and gravel packed)
Other Data: Conductivity and seismic-refraction profiles run; water-level and specific-conductance measurements taken
Topography: Gently sloping gravel-capped terrace (unglaciated area)
Surficial Material: Fluvial terrace deposits - very permeable
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Alfalfa and grass in seep, alternate crop-fallow in surrounding areas
Remarks: Reported excessive nitrate in nearby domestic and stock wells, which was believed to have killed hogs on nearby farm. See figures 5-1, 5-2, and 5-3.

Site 6. Denton region - Barber area

County: Fergus Owner: Larry Barber
Location: T. 19 N., R. 14 E., sec. 28 (north of Denton)
No. of Holes Drilled: 23 (all cased, flushed, and gravel packed)
Other Data: Conductivity and seismic-refraction profiles run; water-level and specific-conductance measurements taken
Topography: Steep to moderate sloping area along Arrow Creek breaks (unglaciated)
Surficial Material: Colluvium (derived from Eagle, Telegraph Creek, and Colorado Formations)
Bedrock Formation: Telegraph Creek and Colorado Shale (Cretaceous)
Vegetation: Some alfalfa in seep areas, alternate crop-fallow in surrounding areas
Remarks: Several cows were killed at nearby reservoir (downstream from test site); farmers on nearby Eagle Sandstone report no seep but deteriorating water quality in shallow wells. See figures 5-1, 6-1, and 6-2.

Site 7. Fort Benton region - Geraldine area

County: Chouteau Owner: City of Geraldine

Location: T. 21 N., R. 11 E., sec. 1

No. of Holes Drilled: 5 (all cased, flushed, and gravel packed)

Other Data: Water-level and specific-conductance measurements taken

Topography: Gently sloping area on glacial sluiceway

Surficial Material: Glacial drift (two tills and meltwater deposits)

Bedrock Formation: Colorado Shale (Cretaceous)

Vegetation: Native sod and grass in town (Geraldine), extensive alternate crop-fallow farmland surrounding town

Remarks: Geraldine lies in the middle of a large discharge area, which seemingly receives excess water from the surrounding area, from the bench to the west, which is capped by the Eagle Sandstone, and from water migrating along the glacial sluiceway.

Site 8. Fort Benton region - Highwood Bench area (7 test areas)

County: Chouteau Owners: Hanford, Bramlette, Booth, Wharran, Long, and Huffman

Location: T. 22, 23 N., R. 7, 8 E.

No. of Holes Drilled Previously: 290

Other Data: Water-level and specific-conductance measurements taken, water samples collected, field-conductivity and seismic-refraction profiles run

Topography: Gently undulating ground moraine

Surficial Material: Glacial drift (two tills, some meltwater deposits)

Bedrock Formation: Colorado Shale (Cretaceous)

Remarks: Saline-seep research on the Highwood Bench was begun in 1969, and each year additional information is gathered to supplement the data network. Last year emphasis was placed on the Huffman test area.

Site 9. Conrad region - Anderson area

County: Pondera Owner: Leroy Anderson

Location: T. 28 N., R. 2 W., sec. 27 (east of Conrad)

No. of Holes Drilled: 16 (all cased, flushed, and gravel packed)

Other Data: Water-level and specific-conductance measurements taken; test holes surveyed-in by SCS

Topography: Gently undulating glacial ground moraine

Surficial Material: Glacial drift (two tills and scattered gravel lenses)

Bedrock Formation: Colorado Shale (Cretaceous)

Vegetation: Alternate crop-fallow farming system; single-row windbreak trends N-S through the middle of the area

Remarks: The ARS (Halverson and Brown) briefly examined the area earlier in the summer of 1974 and drilled two shallow test holes in the area. Discontinuous gravel lenses associated with several small upland potholes seem to be contributing water to the seep. See figures 9-1, 9-2, 9-3, and 9-4.

Site 10. Conrad region - Bokma area

County: Pondera Owner: Ron Bokma

Location: T. 28 N., R. 3 W., sec. 16 (several miles west of Conrad)

No. of Holes Drilled: 25 (all cased, flushed, and gravel packed)

Other Data: Water-level and specific-conductance measurements taken; two water-level recorders installed; test holes surveyed-in by SCS

Topography: Moderately sloping glacial moraine adjacent to the Benton Bench

Surficial Material: Glacial drift (two tills and some meltwater deposits)

Bedrock Formation: Colorado Shale (Cretaceous)

Vegetation: Alternate crop-fallow throughout area, some native sod along bench margin to the west

Remarks: Seeps are numerous around the margins of the Benton Bench. The bench, which is extensively farmed, is capped by Eagle Sandstone. Significant amounts of water seem to be migrating downslope and creating saline conditions. Two shallow holes were drilled earlier in 1974 by ARS (Halverson and Brown). See figures 9-1, 10-1, and 10-2.

Site 11. Conrad region - Gettel, Jones area

County: Cascade Owners: Gettel and Jones

Location: T. 22 N., R. 1 E., sec. 12
T. 22 N., R. 2 E., sec. 6, 7 (southeast of Power)

No. of Holes Drilled: 9 (all cased, flushed, and gravel packed)

Other Data: Water-level and specific-conductance measurements taken

Topography: Gently sloping ground moraine upslope from internally drained basin (Benton Lake)

Surficial Material: Glacial drift (two tills)

Bedrock Formation: Colorado Shale (Cretaceous)

Vegetation: Alternate crop-fallow farming

Remarks: This is a large seep area and possibly could be used for Krall's cropping investigations. If it is used, possibly more holes will be required. The Colorado Shale contains discontinuous hard siltstone lenses in this area. Sommerfelt, several miles south, is draining seep water into one of the siltstone lenses and into nearby coulee, which drains down through research area. See figures 11-1, 11-2, and 11-3.

Site 12. Shelby region - Flesch area
County: Toole Owner: Lester Flesch
Location: T. 33 N., R. 2 W., sec. 1, 2, 11
No. of Holes Drilled: 10 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken; conductivity profiles run; water samples collected; test area surveyed-in by SCS
Topography: Gently sloping ground moraine dissected by small drainageway
Surficial Material: Glacial drift (two tills)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Native sod; alternate crop-fallow farming in headwaters area
Remarks: The area is native sod surrounded by farmland. Recharge potholes are numerous in upper areas. Water seeping into the coulee above the reservoir is believed to have killed four cows. See figures 12-1, 12-2, 12-3, and 12-4.

Site 13. Shelby region - Skari area
County: Liberty Owners: Skari Brothers
Location: T. 34 N., R. 5 E., sec. 24, 25, 26, 35, 36 (north of Chester)
No. of Holes Drilled: 11 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken; water samples collected; test area surveyed-in by SCS; conductivity profiles run
Topography: Ground moraine sloping toward glacial sluiceway and possibly temporary lake
Surficial Material: Glacial drift (two tills; sand and gravel along sluiceway)
Bedrock Formation: Claggett Shale (Cretaceous)
Vegetation: Grass area and crop-fallow farming
Remarks: The area is large and undoubtedly will require more and deeper holes. Bedrock was encountered in only one hole. The sluiceway seems to be an important source of water, but large surrounding recharge area also contributes. See figures 13-1, 13-2, 13-3, and 13-4.

Site 14. Havre region - Hansen area
County: Blaine Owner: Kenneth Hansen
Location: T. 31 N., R. 21 E., sec. 25 (south of Chinook)
No. of Holes Drilled: 9 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken
Topography: Ground Moraine sloping toward small drainageway
Surficial Material: Glacial drift (two tills)
Bedrock Formation: Judith River Formation (Cretaceous)
Vegetation: Alternate crop-fallow farmland, sod drainageway
Remarks: The glacial drift is thick along drainageway, suggesting a buried channel. More holes may be required to adequately characterize the area. See figures 14-1, 14-2, and 14-3.

Site 15. Glasgow region - Newby area
County: Valley Owner: Ruth Newby
Location: T. 30 N., R. 42 E., sec. 14 (northeast of Glasgow)
No. of Holes Drilled: 13 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken; water samples collected; two water-level recorders installed
Topography: Ground maorine sloping toward drainageway
Surficial Material: Glacial drift (outwash over till)
Bedrock Formation: Bearpaw Shale (Cretaceous)
Vegetation: Alternate crop-fallow farmland
Remarks: Water seems to be carried in the weathered zone (3 to 5 feet) of the Bearpaw Shale. A few additional wells may be required in the upper recharge area. See figures 15-1, 15-2, and 15-3.

Site 16. Glasgow region - Rohde (I) area
County: Valley Owner: Dick Rohde
Location: T. 33 N., R. 38 E., sec. 27 (north of Glasgow)
No. of Holes Drilled: 4 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken
Topography: Gently rolling glaciated upland bench area dissected by nearby drainageways
Surficial Material: Glacial drift (till and outwash deposits)
Bedrock Formation: Bearpaw Shale (Cretaceous)
Vegetation: Native sod, which had been scalped
Remarks: These holes were drilled to provide control on lithology and ground water in a native-sod area that was scalped to enhance grass production. These holes will supplement data being collected by Don Ryerson (MSU). Much gravel was encountered, and some of the holes slumped, making it impossible to case them to the bottom. See figures 15-1 and 16-1.

Site 17. Glasgow region - Rohde (II) area
County: Valley Owner: Dick Rohde
Location: T. 33 N., R. 39 E., sec. 29, 30, 31, 32 (north of Glasgow)
No. of Holes Drilled: 8 (all cased, flushed, and gravel packed)
Other Data: Water-level and specific-conductance measurements taken
Topography: Rolling glacial uplands gently sloping toward drainageway
Surficial Material: Glacial drift (till and outwash gravel)
Bedrock Formation: Bearpaw Shale (Cretaceous)
Vegetation: Native sod, untreated
Remarks: This area encompasses a small (150-acre) watershed and contains a 10-acre intermittent lake in the upland area. The holes should help provide baseline data on the hydrologic system of the area. If range improvement techniques (Don Ryerson) are applied to it in the future, changes in water quantity and quality can be easily monitored. See figures 15-2, 16-1, and 17-1.

Preliminary Observations

A few preliminary observations related to the hydrogeologic systems of the test areas are as follows:

1. Considerable moisture has accumulated beneath dryland farm areas throughout the region, especially in comparison to native-sod areas. Other sod areas will be investigated this coming fall. The cultivated drylands typically have 10 to 40 feet of saturated material beneath them in comparison to 0 to 5 feet of saturated profile underlying the native sod.

2. Generalized location maps, water-level and specific-conductance values, and a few selected hydrographs from many of the test areas are included in the previous section. As soon as all the areas are surveyed, detailed maps showing the configuration of the ground surface, water table, bedrock (where possible), and salinity concentrations will be prepared for detailed evaluation of the hydrogeological system at each site.

Because of average to above average spring precipitation, water levels of most shallow test holes drilled in or adjacent to cultivated drylands throughout northern and eastern Montana have risen significantly--an average of about 3 feet.

The abundant precipitation has provided an excellent opportunity to observe the development of numerous seep areas that have differing geological, hydrological, and agricultural conditions. Continued water-level monitoring provided a valuable tool for determining the effectiveness of various cropping systems in controlling the growth of saline seeps.

Despite the above-average precipitation received on the Highwood Bench this spring, no rise in water table has yet been noted beneath the recharge area that has been planted to alfalfa for the last five years (Hanford test area). This is particularly encouraging because in other nearby areas planted to cereal grains the water table has risen significantly.

3. Consultation with numerous farmers, ranchers, district conservationists, and county extension agents indicates that the deterioration of shallow ground-water supplies and local surface-water supplies is more widespread than previously believed. As a result an areal field evaluation of selected wells, springs, streams, and reservoirs has been begun. Preliminary water-quality data indicate

that in addition to high dissolved solids and trace metal concentrations, nitrate (NO_3) values are very high, particularly in the Denton, Shelby, and Geraldine regions. Reported or confirmed (Geraldine area) nitrate poisoning of livestock has occurred in each of these areas. Specific-conductance values (an approximate measurement of total dissolved solids) of water in many of the test holes are shown on the attached test-site maps.

4. One of the long-term objectives of the Bureau's saline-seep research effort is to evaluate the salinization potential in northeastern Montana. Toward this goal current research objectives include the determination of the water-soluble salt load within the surficial aquifer at the test-site areas. Methods commonly employed in agricultural studies (saturated soil extracts, etc.) were not thought applicable because: (1) they do not yield consistant leachate volumes; (2) the leachates tend to have higher pH values than unsaturated soil waters (which may suppress the dissolution of carbonate minerals); (3) they are not concerned with complete recovery of all soluble material. Consequently, the Bureau of Mines and Geology has been involved with

developing a relatively inexpensive method of extracting the water-soluble salt load from augered samples, which simulates the natural environment, provides quantitative data on the soluble load, and meets the requirements of 80 percent recovery with a reproducibility of ± 10 percent.

Preliminary investigations with natural material collected on field trips to saline-seep areas determined two significant problems: (1) incomplete dissolution of calcium carbonate was common if the pH was not controlled; and (2) gypsum reactivity was very slow (this is believed to be the result of the iron hydroxide coatings noted upon the natural material). Both column leaching and batch reactor approaches were initially investigated. The column method has the advantage of better simulating the natural weathering environment, in that distilled water (equivalent to rainfall) is continuously introduced to the system, and a leaching profile (leach front) is established. However, the materials being studied commonly contain a large fraction of expandable clays, which reduced flow through the column to less than 5 percent of the acceptable rate. Rather than mix the samples with a large amount of "inert" beads to increase permeability, development emphasis was placed upon the use of a batch reactor. The advantages of using a batch reactor include: (1) greater ease of temperature control; (2) ability to continuously monitor and adjust pH; (3) less technician time required (no flow adjustments); (4) less expensive, specialized equipment required; and (5) less time needed to achieve the same level of recovery.

The minerals (solid salts) that should be dissolved to determine the soluble salt load fall into two catagories, the rapidly (and highly) soluble salts, such as the sodium and magnesium sulfate minerals, and the more slowly (and generally far less) soluble salts, such as the calcium carbonate and sulfate minerals. In order to increase the solution rate, different sample preparation techniques and experimental temperatures were tested. A rod mill is used to grind the oven-dried (55°C) samples. About 80 percent of the material will pass through a 200-mesh sieve after grinding. The dissolution runs are conducted at

$55^{o}C$ in a 5-liter beaker containing 10 grams of sample and 3 liters of deionized water.

The material used in evaluating the procedures (Newby site, near Glasgow) contains 1.9 to 2.0 weight percent water-soluble salts. Recovery of gypsum additions is at the 95 percent level after 22 hours using either deionized water or deionized water with the pH adjusted to 4.0. Reproducibility of the total cation milliequivalents leached is within 5 percent, and the reproducibility for milliequivalents of alkali metals and of alkaline earths is within 10 percent. Better reproducibility can probably be achieved by homogenizing the samples after grinding (the materials used were grab samples from the rod mill grinding process). Experiments still in progress lead us to believe that adjusting the leach solution to a pH of 5.0 will provide nearly complete recovery of the soluble salts without subjecting the clay minerals to significant lattice degradation during the leaching period. Consequently, it seems that we now have a relatively inexpensive laboratory procedure, offering adequate recovery and reproducibility, that may be used to determine the water-soluble salt load within the surficial aquifers in saline-seep areas.

5. The thickness of glacial drift across northern Montana is greater than previously thought (more than 70 feet), consequently, many holes along the margins of the research areas did not reach bedrock. The drilling depth was limited to 69 feet, but additional augers have been ordered, which will extend our capability in the future. Saline-seep development seems to be most pronounced in areas where the surficial material overlying bedrock is relatively thin. Deeper test holes in several areas lacking apparent seep development are planned this coming year.

6. Correlation of resistivity data (four-probe wenner configuration) with pertinent horizons--water table, permeable zones, and top of bedrock--was fair to good in most areas, but in several places correlation was poor. Also, instability in current input was noted in several discharge areas, which caused inconsistant resistivity values. Additional experimental and development work is needed.

Difficulties Encountered

No major difficulties have occurred. Minor problems were as follows:

1. Obtaining good representative cores proved to be very difficult in some areas. The normal 18-inch split-tube core barrel was extremely slow and time consuming, so we borrowed a set of 5-foot Giddings core barrels from Paul Brown, which greatly speeded the operation. In many areas, however, the ground was still too hard or contained too much water or too much gravel for coring. A set of the Giddings core barrels and the appropriate adaptors have been ordered.

2. Depth has been limited to 69 feet because of the lack of 6-inch augers. Seven additional augers were ordered, but delivery was delayed until January 1975. In several of the areas, one or two additional holes drilled to bedrock will probably be required.

3. Because of excessive moisture received during the winter and spring months, access of heavy equipment to research sites was impossible, consequently the aquifer and infiltration testing will have to be delayed until the fall of 1975. The weather also hampered the engineers from the Soil Conservation Service in surveying the test areas and preparing accurate base maps. Surveys have been completed on four of the test sites.

Future Plans

Future plans are closely related to the objectives and goals listed in the first section and included in the recent contract for fiscal year 1976. Major emphasis will be placed on the following:

1. Drilling program

   Drill additional test holes to supplement hydrogeologic data at existing sites; to support other research projects by Krall, Ferguson, Brown, and Custer; to examine cropped areas with no apparent dryland salinity problems; and to characterize several other seep areas if time permits.

2. Water-level monitoring

   Monitor all existing and new test holes periodically during the year, especially during the spring months.

3. Water-quality program

   Inventory and collect numerous water samples across the northern plains to predict water-quality trends and delineate problem areas. Much of the work will be supported by the Old West Regional Commission.

4. Soluble salt load evaluation

   Water-soluble salt loads will be determined from selected test-hole samples to evaluate the salinization potential of the surficial material across Montana.

Summary of Project Expenditures
for Fiscal Year 1975

Personal Services		
Salaries	$12,384.00	
Benefits	1,112.12	
Total Personal Services		$13,496.12
Operating Expenses		
Supplies	$ 1,115.99	
Telephone & Postage	50.69	
Travel	12,251.77	
Total Operating Expenses		$13,418.45
Equipment		$ 104.37
Other		
Drilling	$11,830.66	
Casing	2,225.00	
Augers	824.99	
Total Other		$14,880.65
Total Expenditures		$41,899.59

Remaining Balance - $13,100.41

The remaining balance has been budgeted for fiscal year 1976 to help cover drilling costs and personal services as outlined in the current contract proposal.

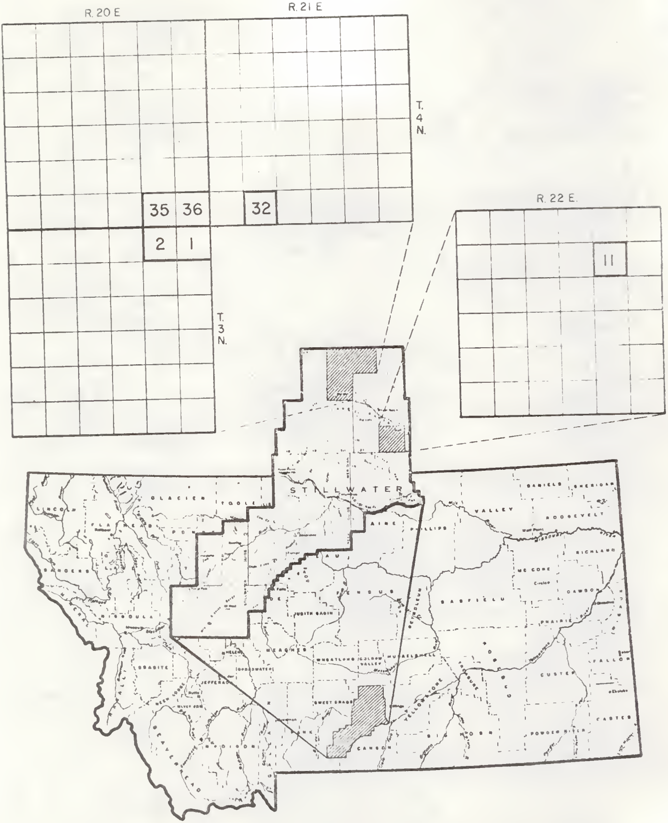


Figure 1-1.--Index map of Stillwater County, Montana, showing approximate locations of the Brickley, Hoagland, and Schneidt test areas.

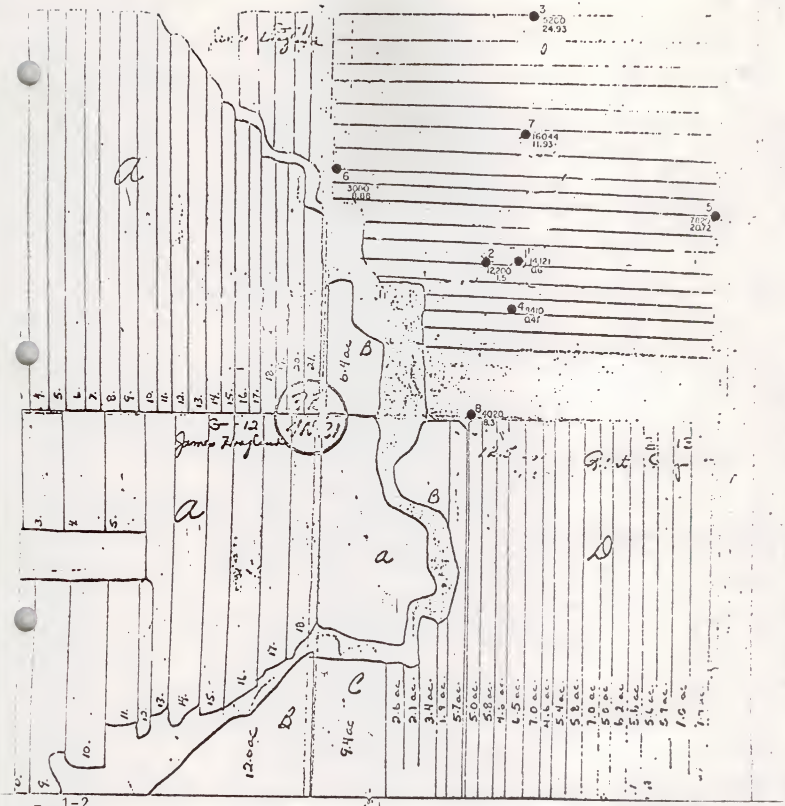
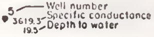
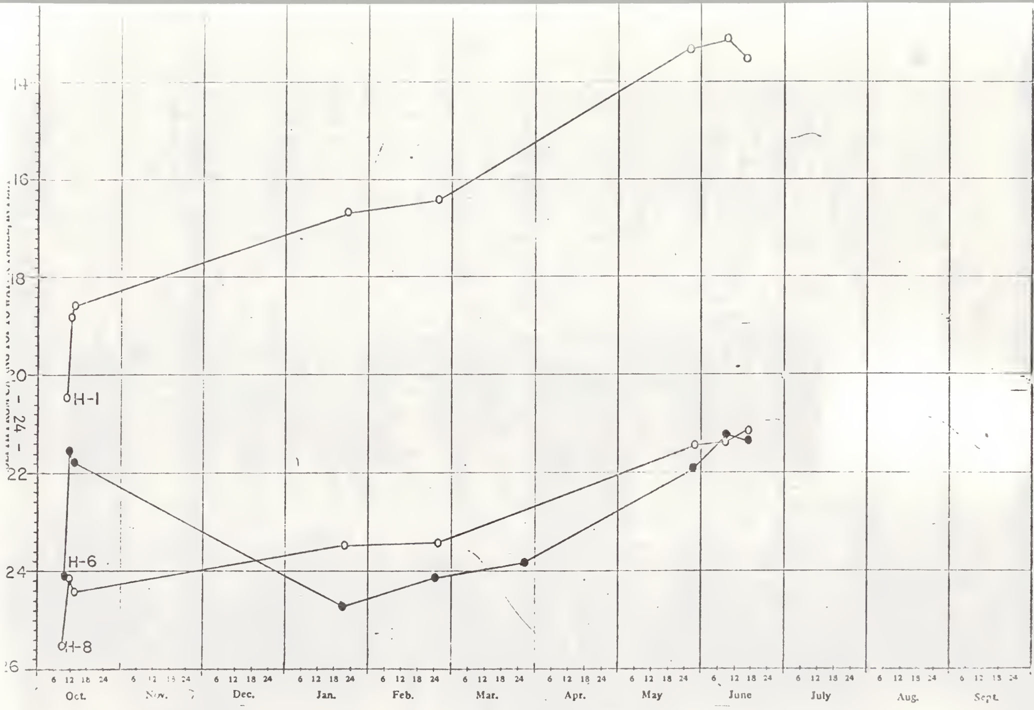


Fig. 1-2

ASCS Photograph

Figure 1-2.-- Sketch map of Hoagland Test Area, Stillwater County, Montana; T. 4N R. 21E Sec. 32, showing location of test wells, specific conductivity values, and depth to water on 5/26/75.





74-75

TIME, IN DAYS

Hole no.

Test plot HOAGLAND

Remarks

Figure 1-3.--Hydrographs of selected wells on Hoagland test area

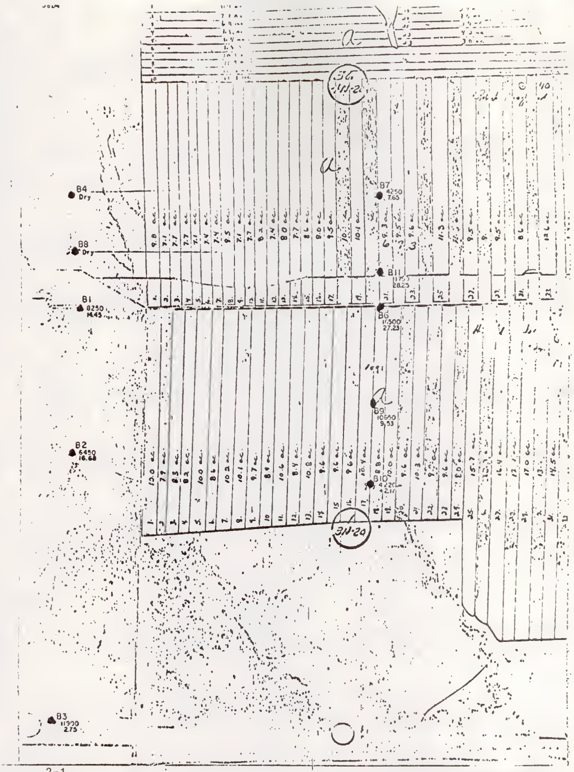


Fig. 2-1

ASCS Photograph

Figure 2-1.-- Sketch map of Brickly, Holland, and Doley Test Area, Stillwater County, Montana; showing location of test wells, specific conductivity values, and depth to water on 5/26/75.

5 — Well number
3619.5 — Specific conductance
19.5 — Depth to water

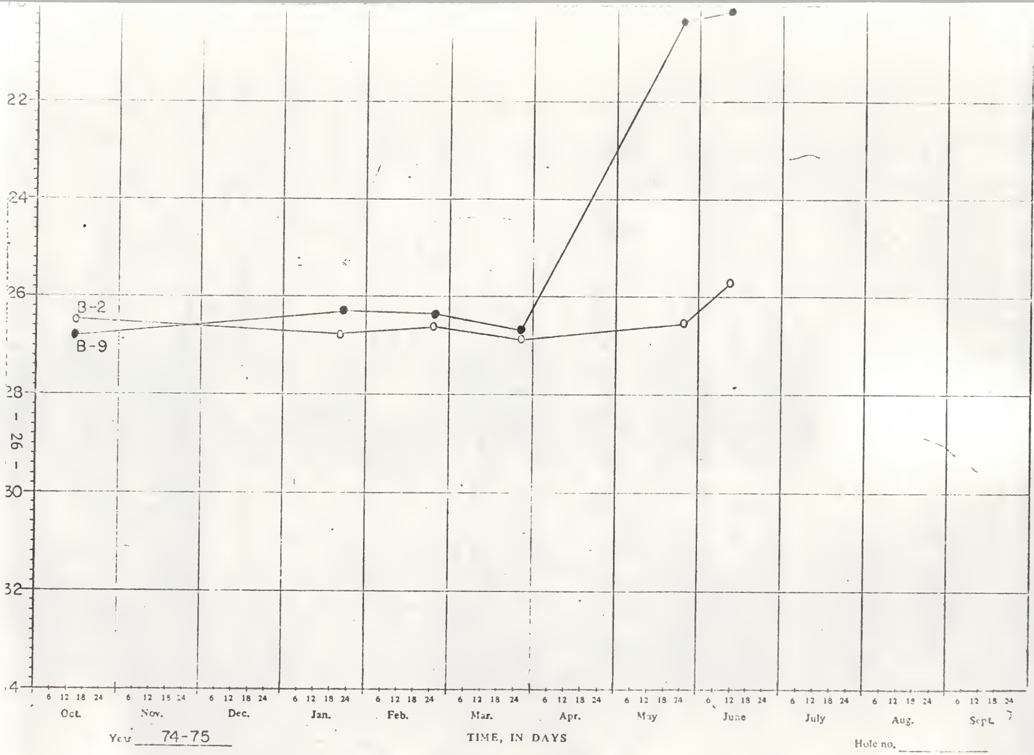


Figure -2.--Hydrographs of selecte wells on Brickley, Hollan and Doley test areas

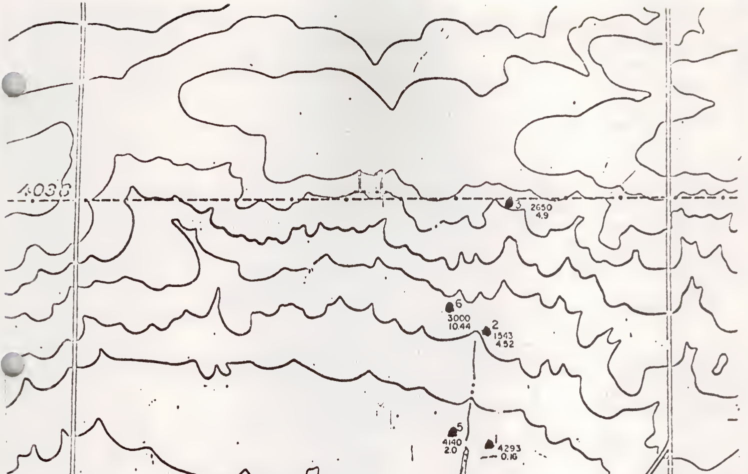


Fig. 3-1

USGS Molt Topographic

Figure 3-1.-- Topographic map of Schneidt Test Area, Stillwater County, Montana; T. 1N R. 22E Sec. 11 showing location of test wells, specific conductivity values, and depth to water on 5/26/75.

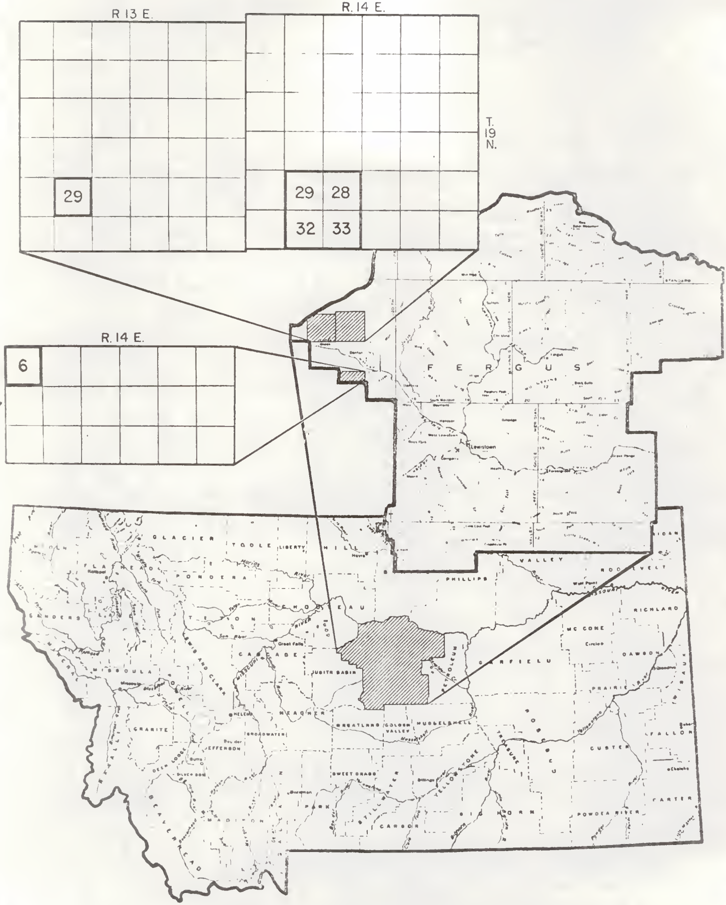


Figure 5-1.--Index map of Fergus County, Montana, showing approximate locations of Brinkman, Barber, and Melton test areas.

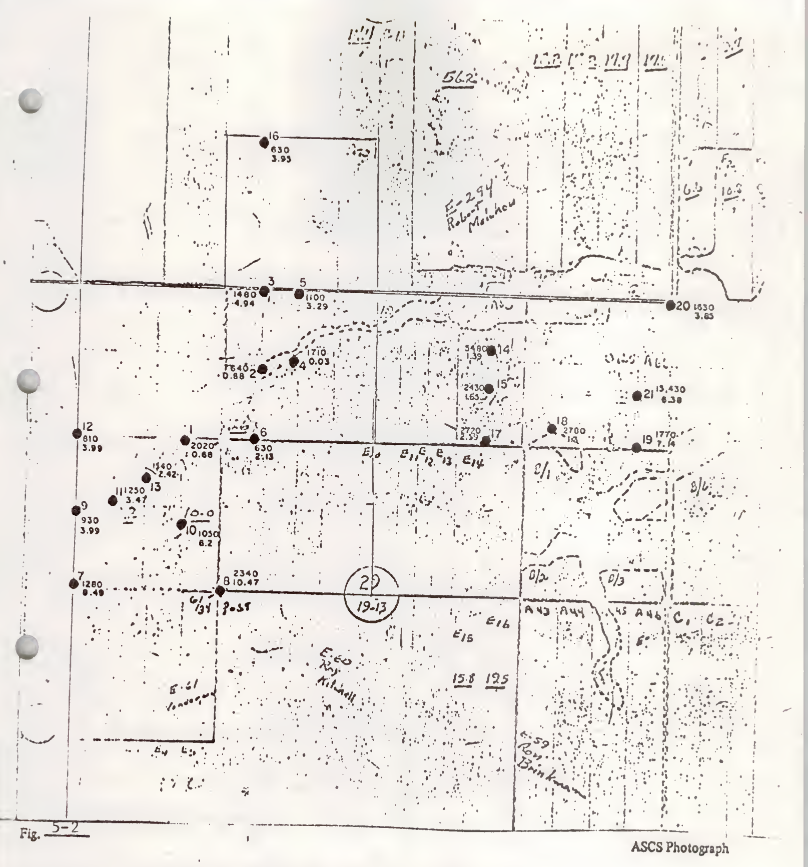


Fig. 5-2

ASCS Photograph

Figure 5-2.-- Sketch map of Brinkman Test Area, Fergus County, Montana; T. 19N R. 13E Sec. 29, showing location of test wells, specific conductivity values, and depth to water on 5/27/75.

5 — Well number
3619.3 — Specific conductance
19.5 — Depth to water

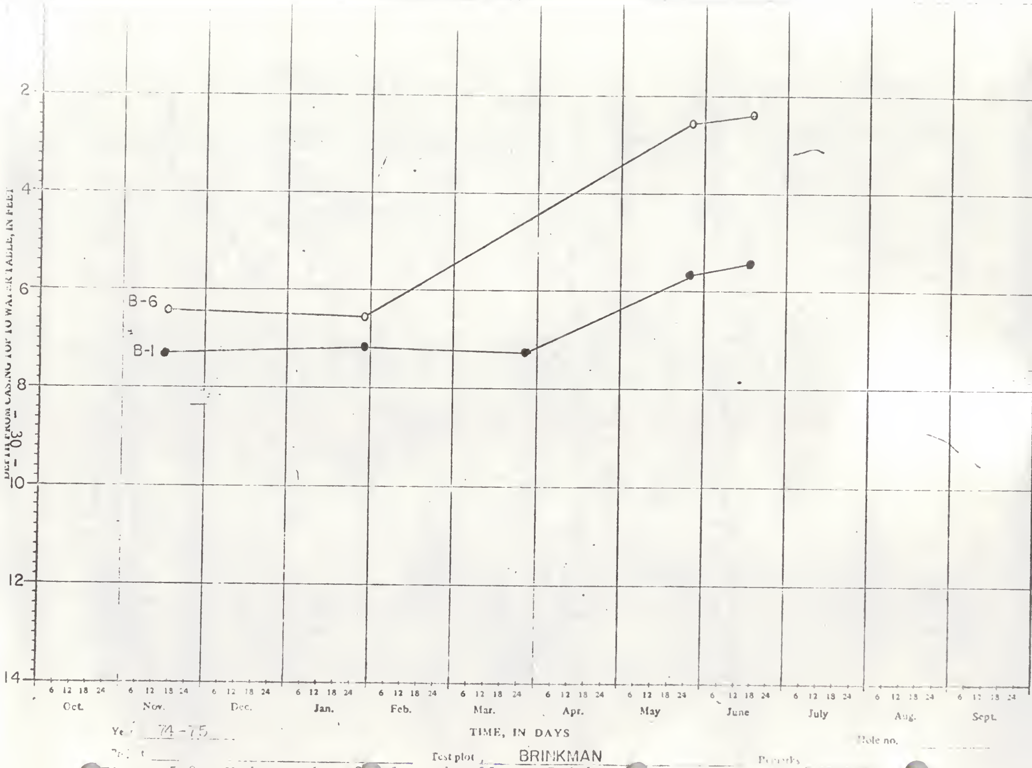


Figure 5-3.--Hydrographs of selected wells on Brinkman test area.

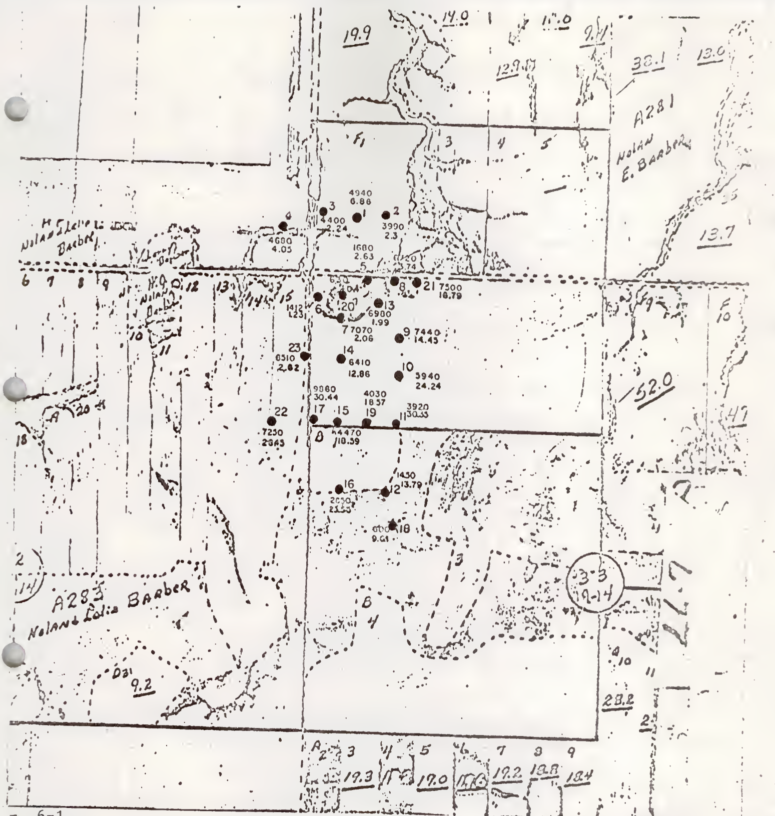
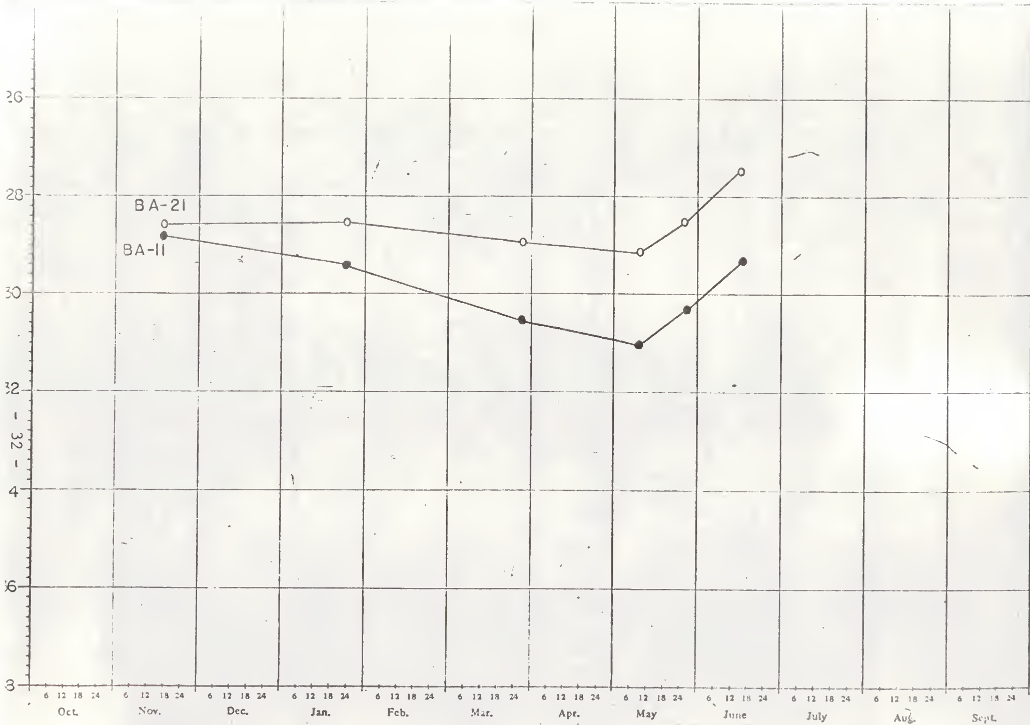


Fig. 6-1

ASCS Photograph

Figure 6-1.-- Sketch map of Barber Test Area, Fergus County, Montana; T. 19 R. 14 Sec. 29, 28, 32, 33, showing location of test wells, specific conductivity values, and depth to water on 5/27/75.



Year 74 - 75

Project

Test plot BARBER

Hole no.

Remarks

Figure 6-2.--Hydrographs of selected test holes on Barber test area.

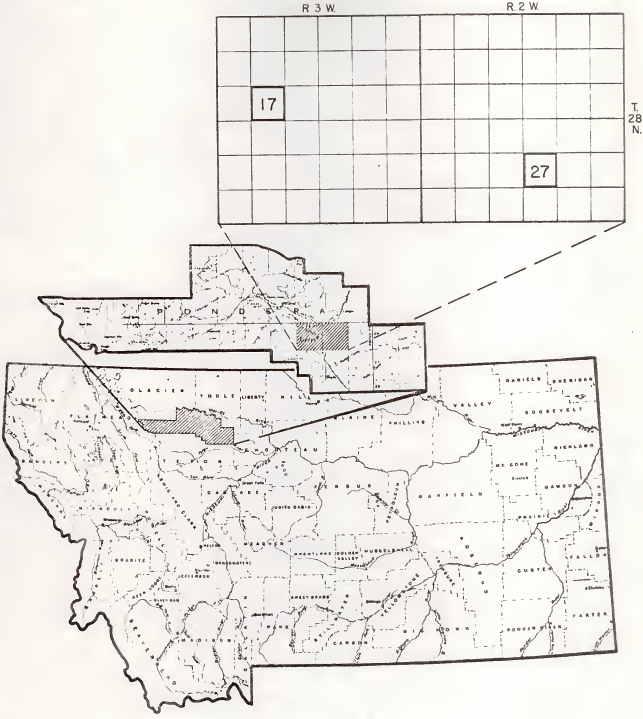


Figure 9-1.--Index map of Pondera County, Montana, showing approximate locations of Anderson and Bokma test areas.

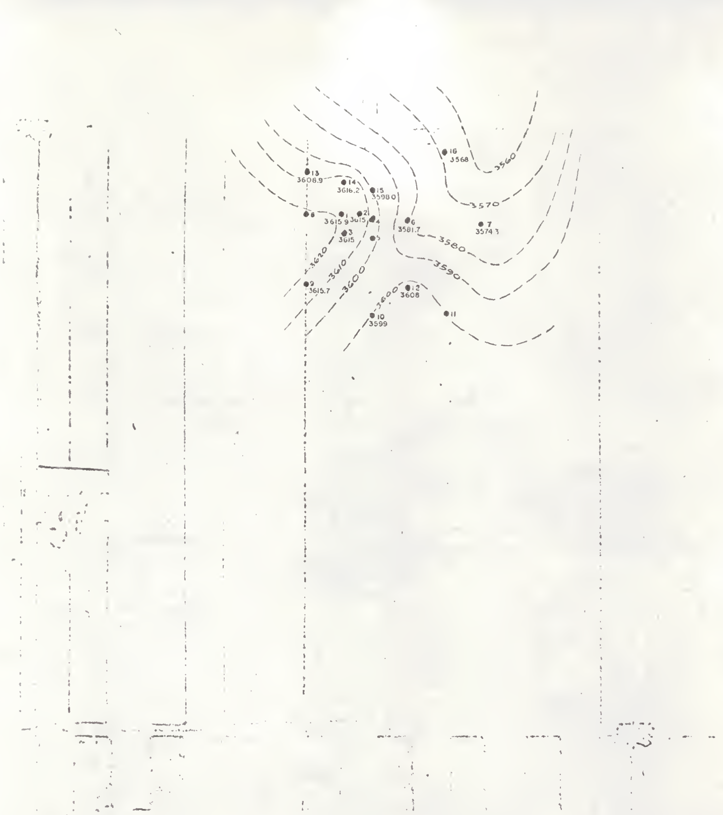


Fig. 9-2

ASCS Photography

Figure 9-2.--Sketch map of Anderson Test Area, Pondera County, Montana; T. 28N R. 2W Sec. 27, showing location of test wells and potentiometric surface.

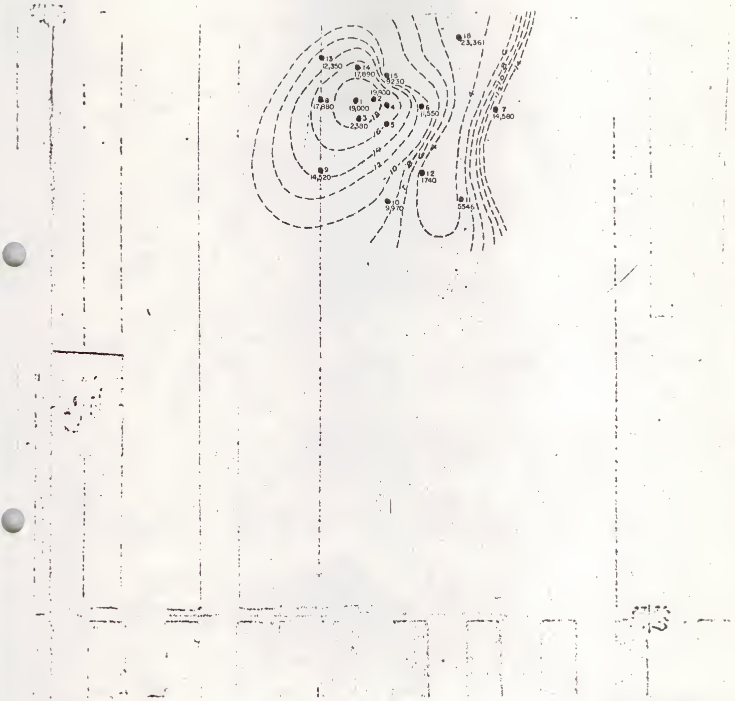


Fig. 9-3

ASCS Photograph

Figure 9-3. - Sketch map of Anderson Test Area, Pondera County, Montana; T. 28N R.2W Sec. 27, showing location of test wells and isocons of specific conductivity.

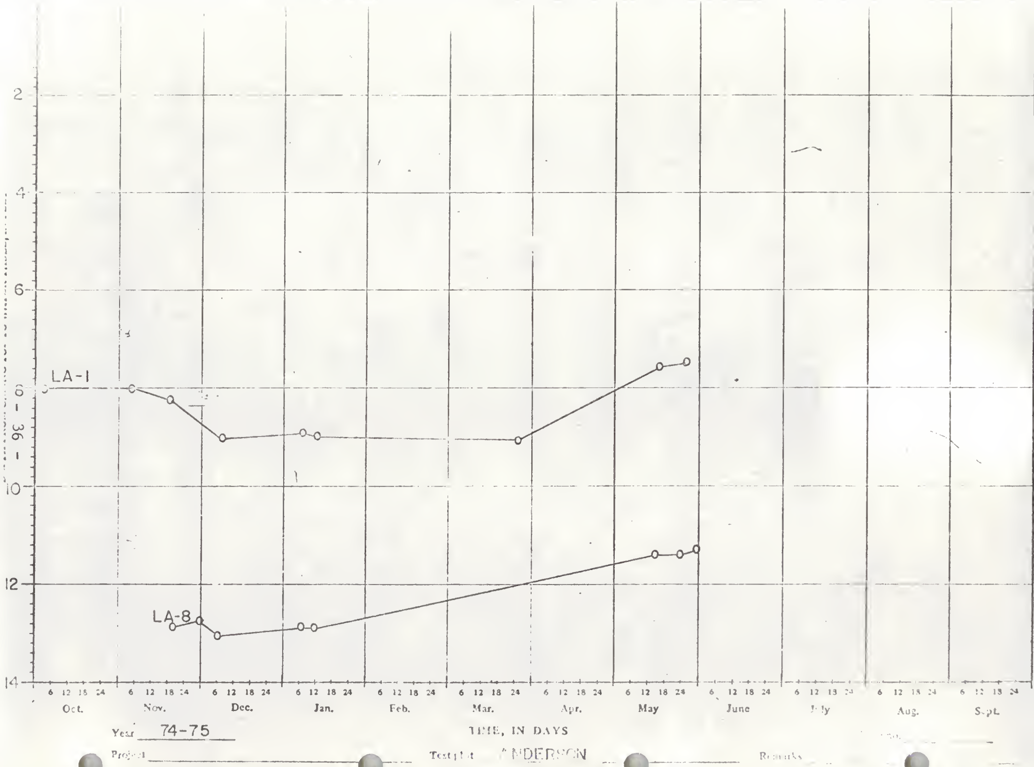


Figure 9-4.--Hydrograph of selected test holes on Anderson test area.

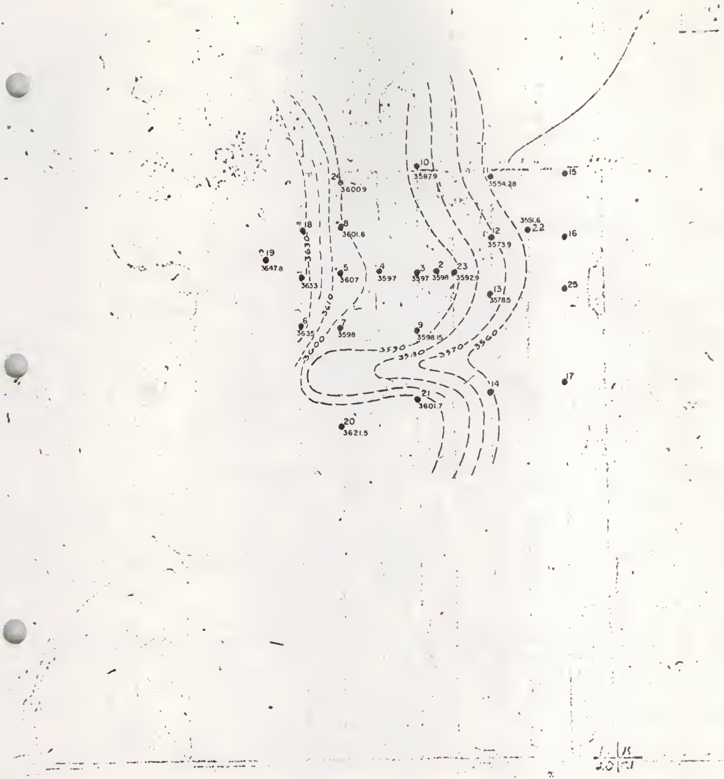
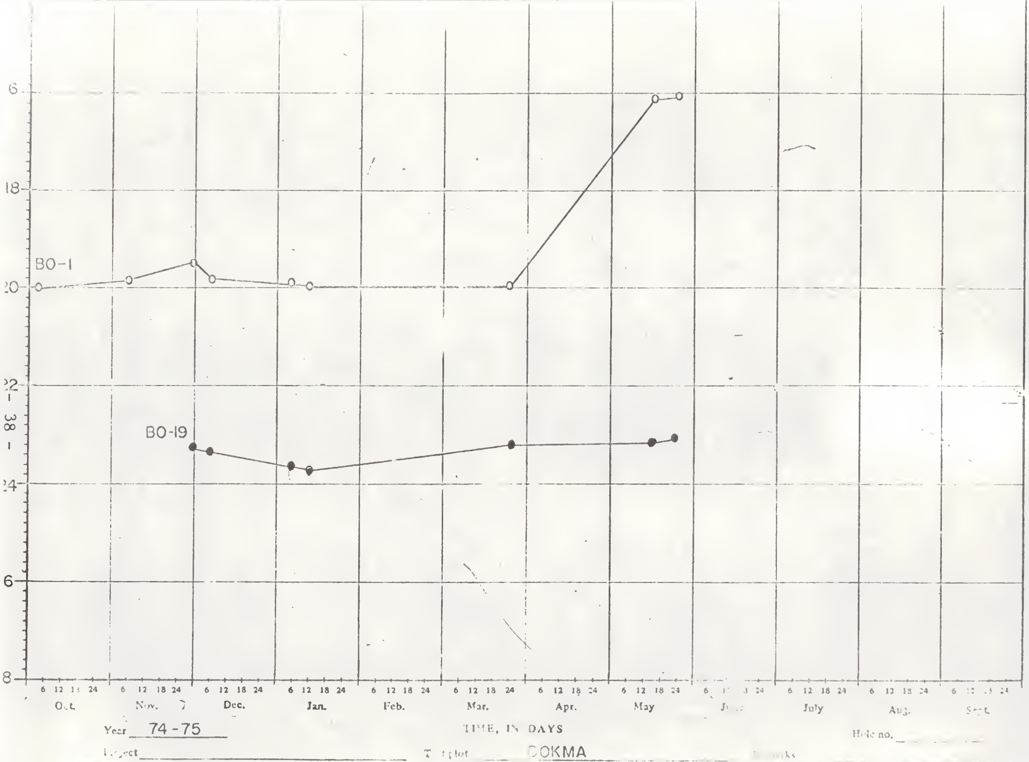


Fig. 10-1

ASCS Photography

Figure 10-1.-Sketch map of Bokma Test Area, Pondera County, Montana; T. 38N R. 3W Sec. 17 showing location of test wells and potentiometric surface.



igure 10-2.--Hydrograph of lected wells on Bokma tes area.

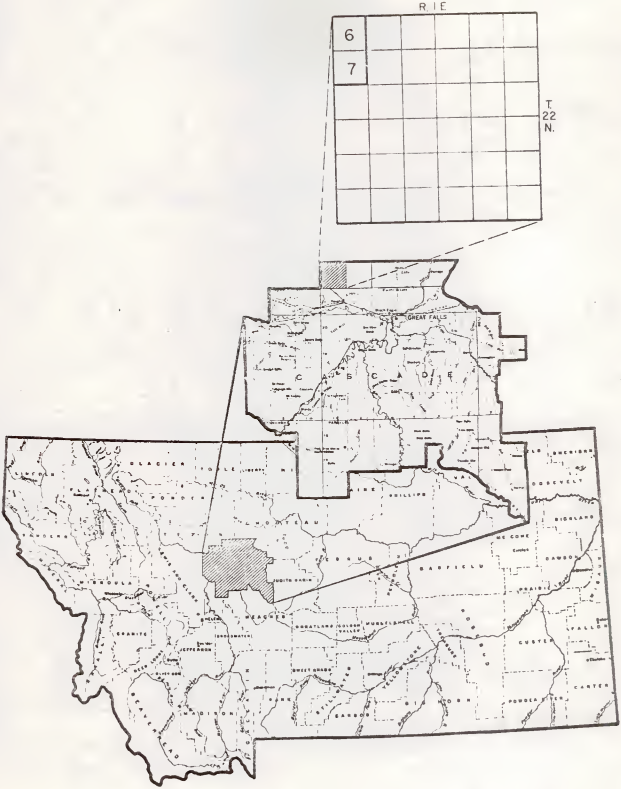


Figure 11-1.--Index map of Cascade County, Montana, showing approximate location of Gettel-Jones test area.

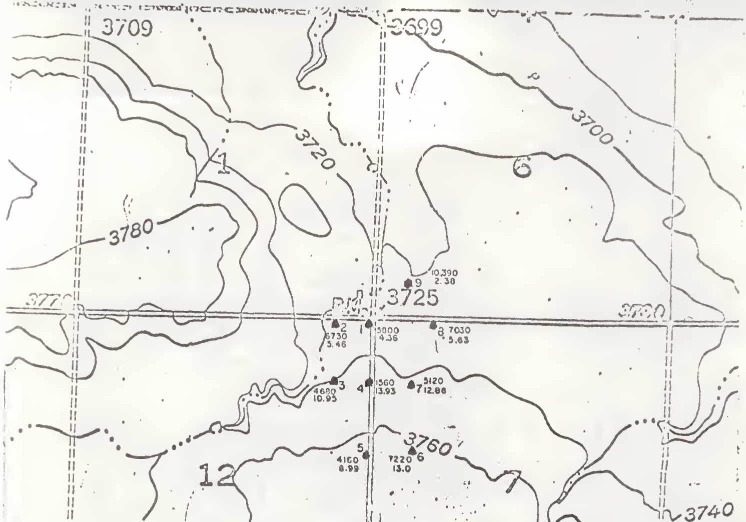


Fig. 11-2

Interior, Geological Survey

igure 11-2. -- Topographic map of Gettel-Jones Test Area. T. 22N R. 1E Sec. 12; and T. 22N R. 2E Sec. 6, 7, Pondera County, Montana; showing location of test wells, specific conductivity values, and depth to water on 5/16/75;

5 — Well number
3619.3 — Specific conductance
Depth to water

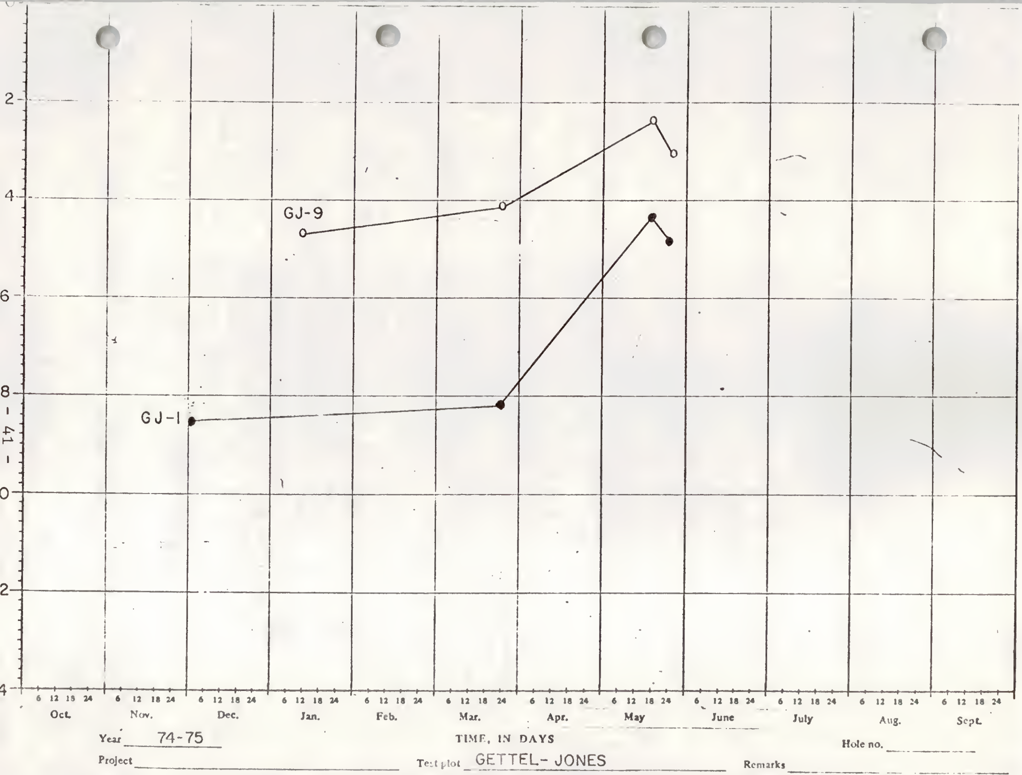


Figure 11-3.--Hydrographs of selected wells on Gettel-Jones test area.

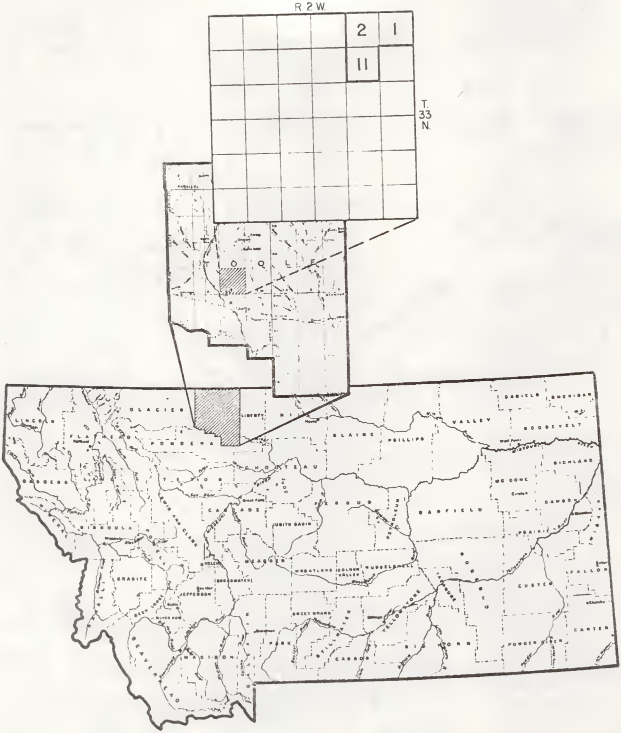


Figure 12-1.--Index map of Toole County, Montana, showing approximate location of Flesch test area.

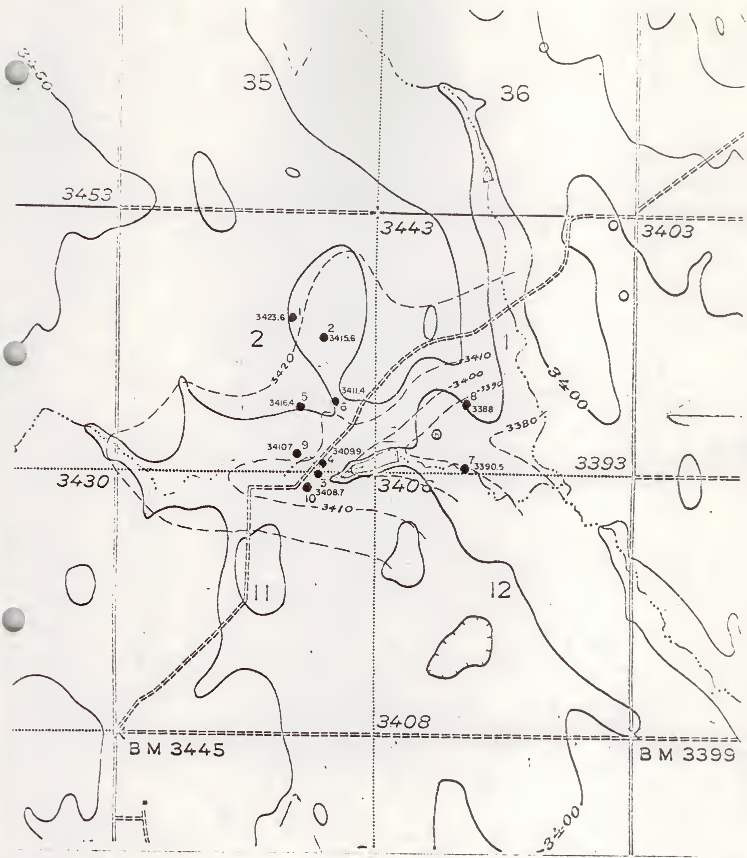


Fig. 12-2

Interior, Geologic Survey

Figure 12-2.-- Topographic map of Flesch Test Area. T. 33N R. 2W Sec. 1, 2, and 11, Toole County, Montana; showing location of test wells and potentiometric surface.

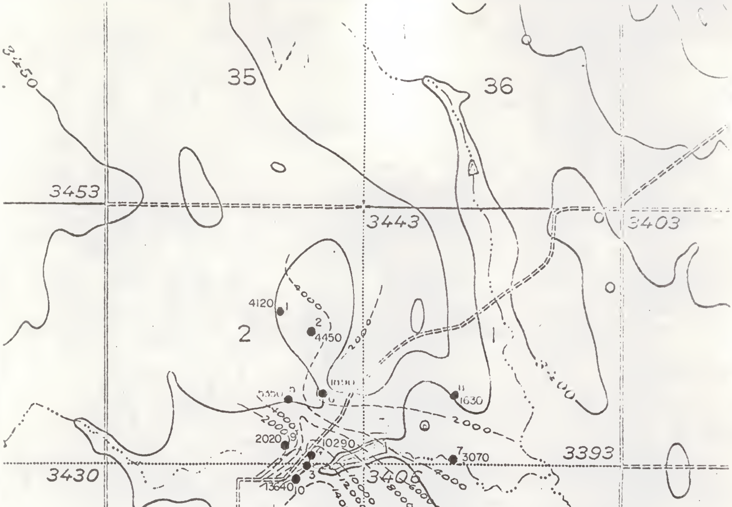


Fig. 12=3

Interior, Geologic Survey

Figure 12-3.--Topographic map of Flesch Test Area. T. 33N R. 2W Sec. 1, 2, and 11, Toole County, Montana; showing location of test wells and isocons of specific conductivity.

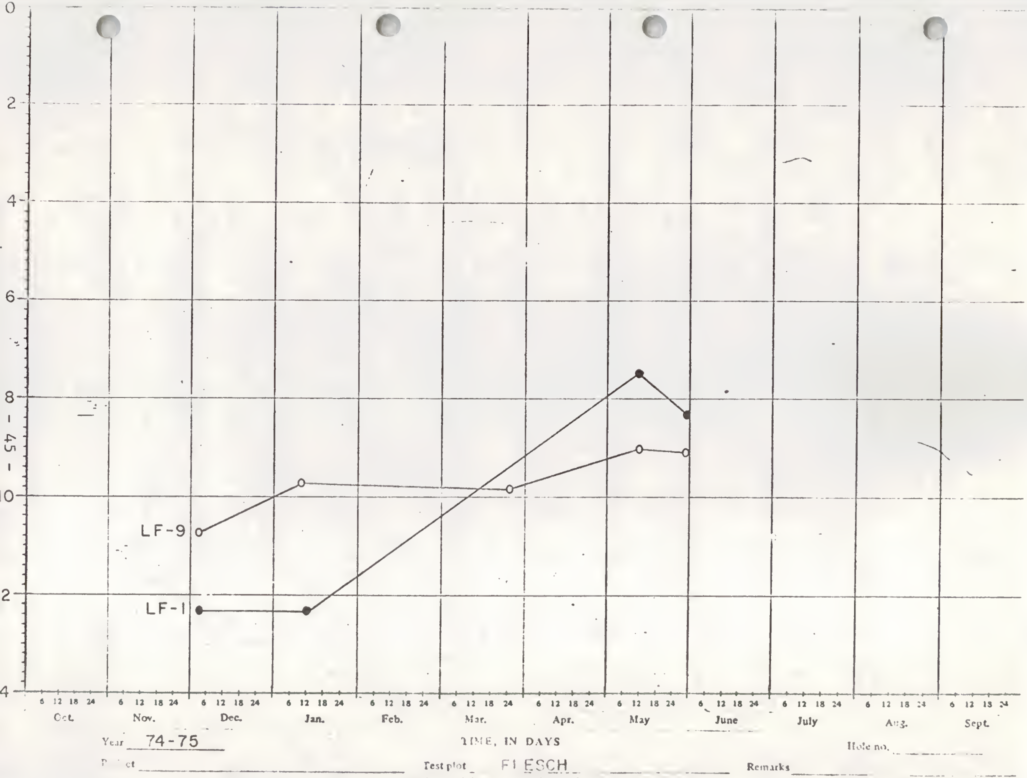


Figure 12-4.--Hydrograph of selected wells on Flesch test area.

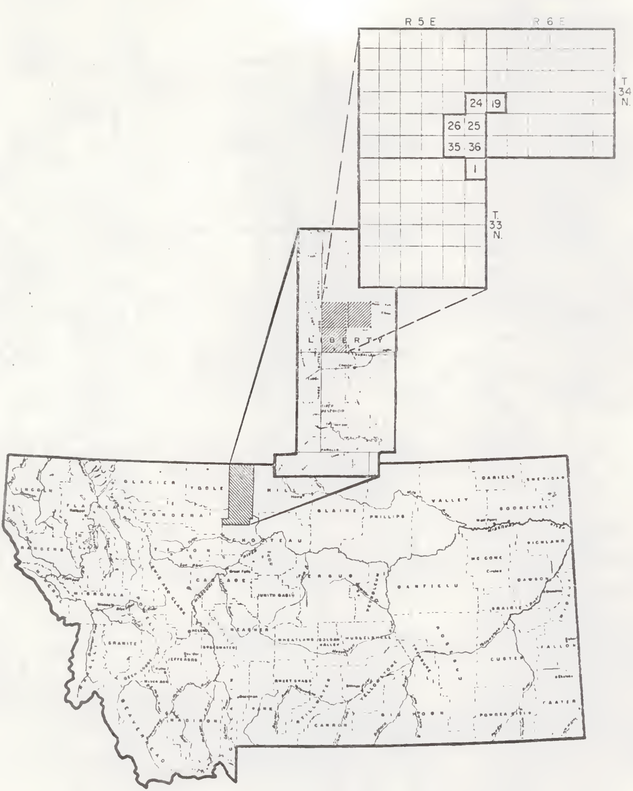


Figure 13-1.--Index map of Liberty County, Montana, showing approximate location of Skari test area.

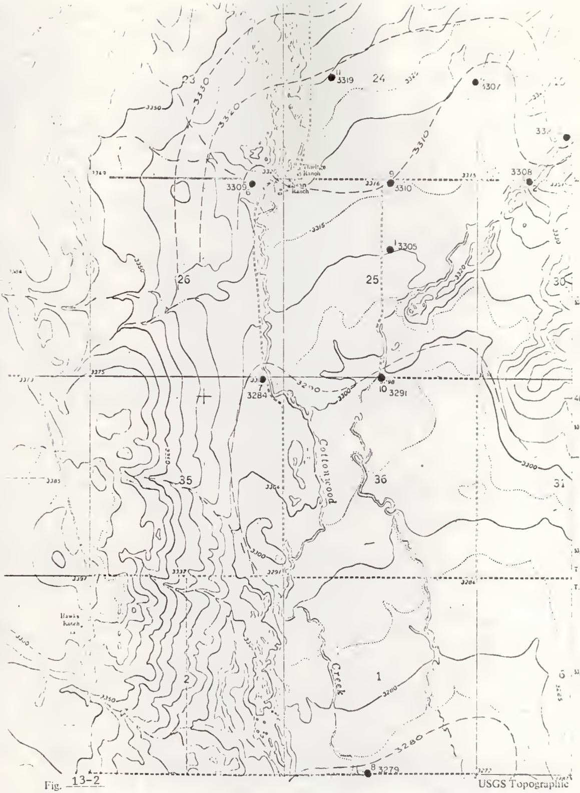


Fig. 13-2

USGS Topographic

Figure 13-2.-- Topographic map of Skari Test Area, Liberty County, Montana; T. 34N R. 5E Sec. 24, 25, 26, 35, and 36. T. 34N R. 6E Sec. 19, and 30, showing location of test wells and potentiometric surface.

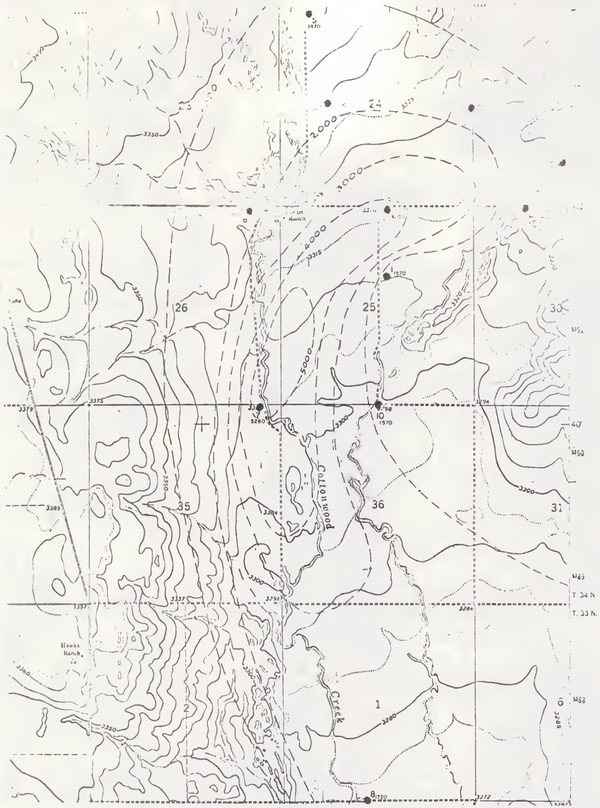
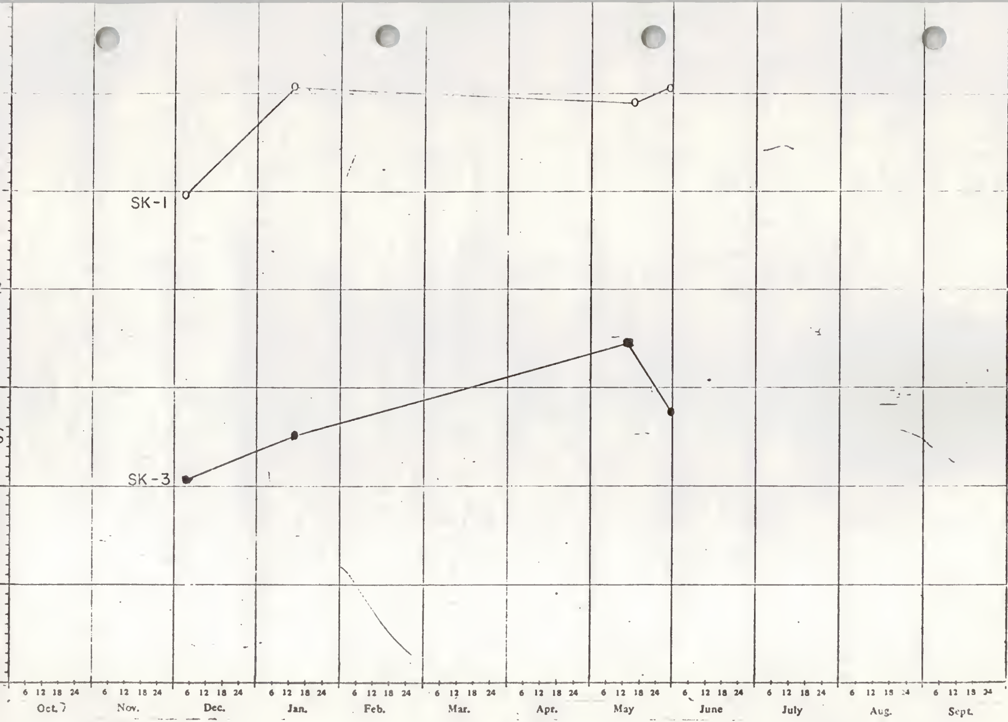


Fig. 13-3

USGS Topographic

Figure 13-3.--Topographic map of Skari Test Area, Liberty County, Montana; T. 34N R. 5 E Sec. 24,25,26, 35, and 36. T. 34N R. 6 E Sec. 19, and 30, showing location of test wells and isocons of specific conductance.



Year 74 - 75

Hole no.

Project

Test plot SKARI

Remarks

Figure 13-4.--Hydrographs of selected wells on Skari test area.

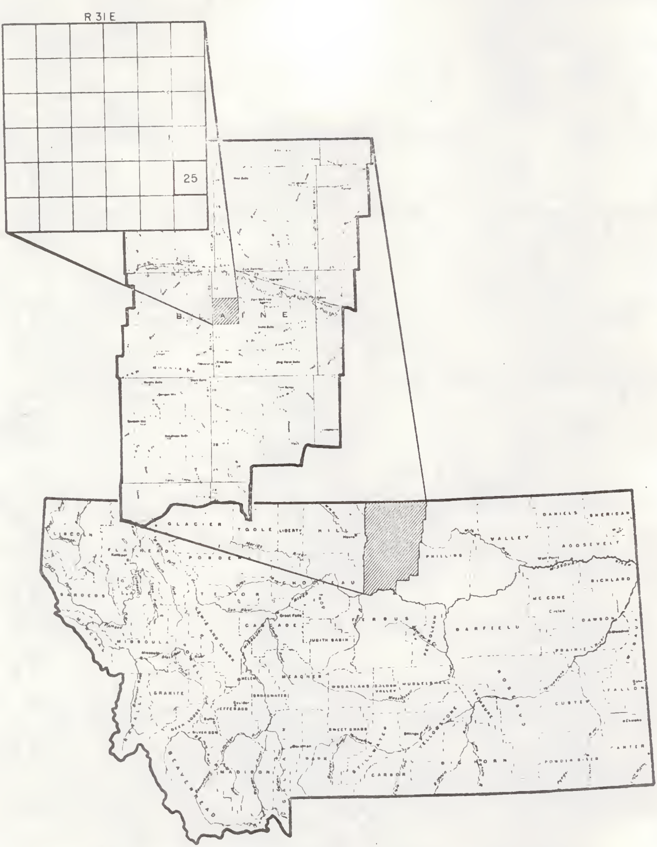


Figure 14-1.--Index map of Blaine County, Montana, showing approximate location of Hansen test area.

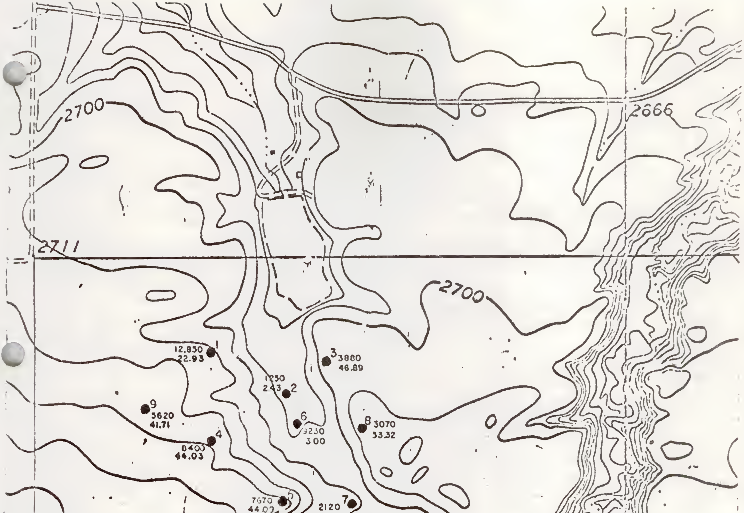
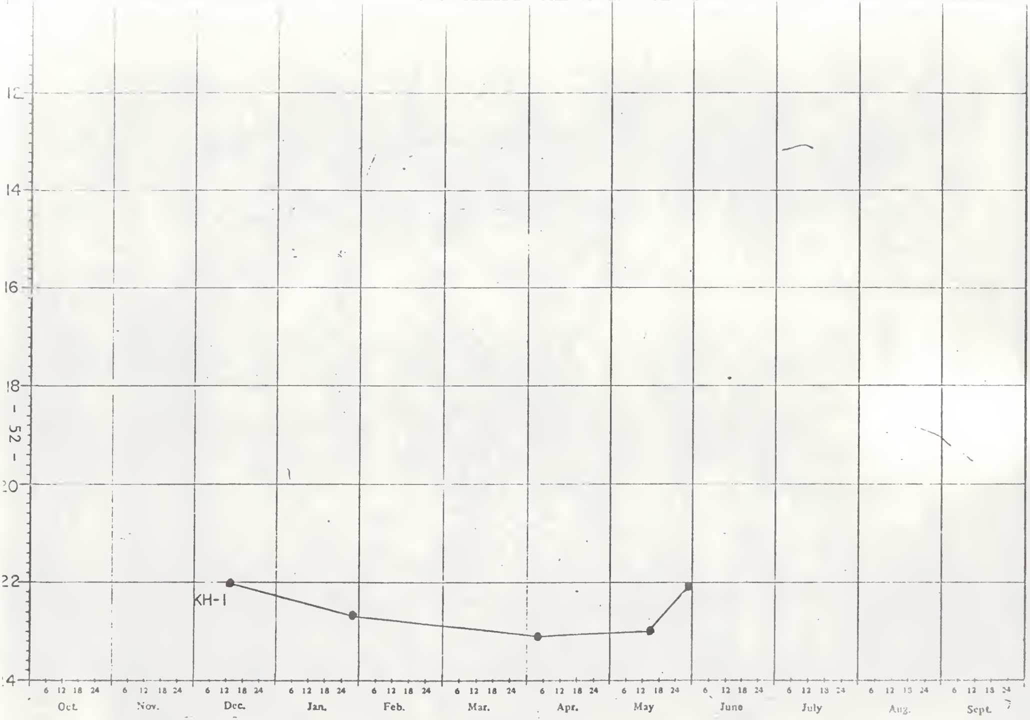


Fig. 14-2

USGS Topographic

Figure 14-2.-- Topographic map of Kenneth Hansen Test Area, Blaine County, Montana; T. 31N R; 21E Sec. 25, showing location of test wells, specific conductivity values, and depth to water on 5/15/75.

5 — Well number
Specific conductance



Year 74-75

Hole no.

Project

Test plot HANSEN

Remarks

Figure 14-3.--Hydrograph of [illegible] selected well on Hansen [illegible]st area.

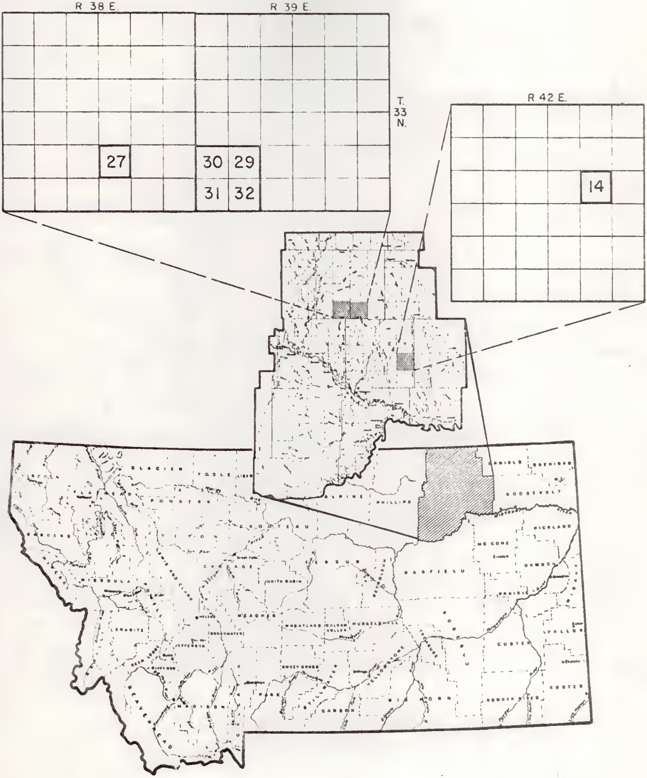


Figure 15-1.--Index map of Valley County, Montana, showing approximate location of Newby and Rhode test areas.

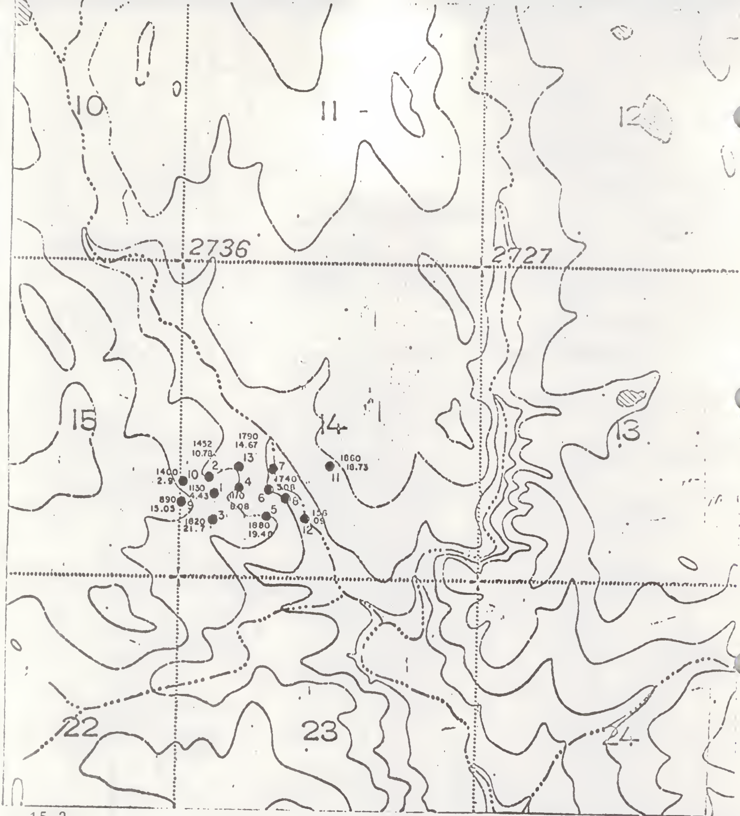
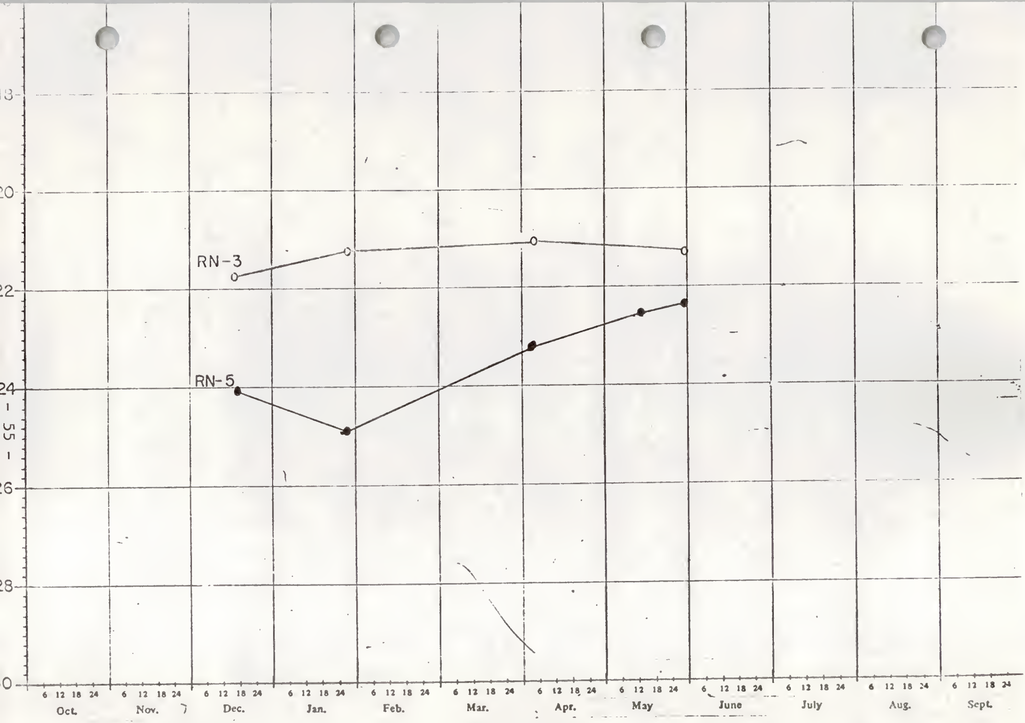


Fig. 15-2

Interior, Geologic Topographic

Figure 15-2.-- Topographic map of Newby Test Area, Valley County, Montana; T. 30N R. 42E Sec. 14 showing location of test wells, specific conductivity values, and depth to water on 5/15/75.

5 — Well number
3619.3 — Specific conductance
19.5 — Depth to water



TIME, IN DAYS

Year 74-75

Hole no.

Project

Test plot NEWBY

Remarks

Figure 15-3.--Hydrographs of selected wells on Newby test area.

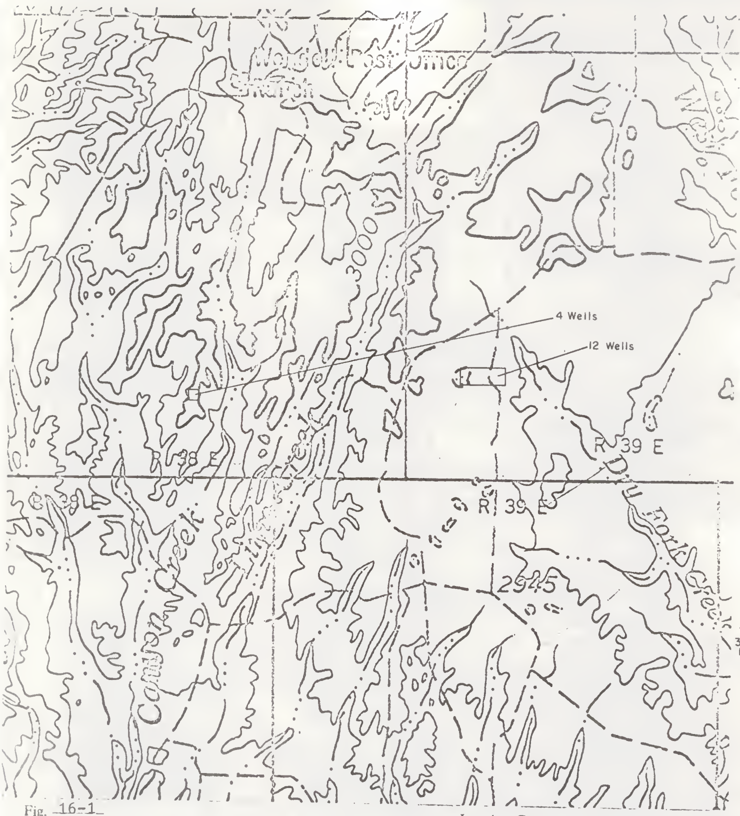
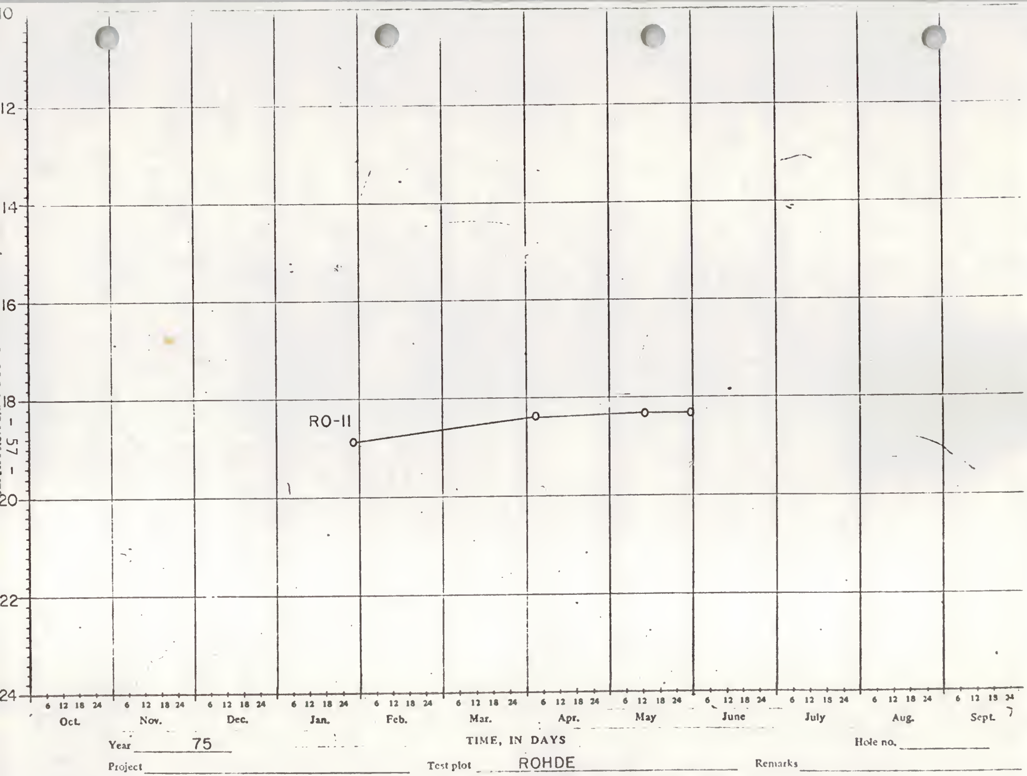


Fig. 16-1

Interior, Geological Survey

Figure 16-1.-- Topographic map showing location of the Rhode Test Area. Four wells in T. 33W R. 38E and twelve in T. 33W R. 39E.



Year 75

Hole no.

Project

Test plot ROHDE

Remarks

Figure 17-1.--Hydrograph on a selected well on Rohde (II) test area.

THE PROCESS OF WATER SALINIZATION IN AREAS OF SALINE SEEP IN EASTERN MONTANA

A final report to the Department of State Lands
submitted by the Department of Geology, University of Montana,
Missoula, Montana.

Project Director	Principle Investigator
Graham R. Thompson Associate Professor	Stephan G. Custer Graduate Student

Date: July 30, 1975

I. Introduction

This is a report for the first half of a two-year study. The report is directed to laymen. The conclusions are in some cases tentative at this stage of the study and subject to assumptions. If the conclusions are to be used in detail or applied scientifically, the reader is directed to the appendix which reports the technical results and discussions.

II. Objectives

A. An intensive study is being conducted on three sites which have saline seep in an effort to explain the process by which ground water becomes saline.

1. Determinations are being made of the total amount and distribution of the major ions in the soil and surface rock available for delivery into the ground water system. The major ions in seep water are sodium, magnesium, calcium, sulfate and nitrate.
2. Investigations of the mineralogy and chemistry of the systems as well as the geologic origins of the ions are being made to identify the process which delivers the ions to the water.
3. A model of the process by which the water becomes salty is being developed using mineralogic, chemical, and geologic data from this study and the hydrologic and water quality data collected by the Montana Bureau of Mines and Geology.

B. Extensive investigation of saline seep is being conducted to develop criteria for prediction of where saline seep is most likely to occur or be most severe, and to produce a map of where these locations are in Montana. The criteria being investigated are mineralogy, chemistry, source of the ions, hydrology, and land use.

III. Project Activities

A. Drilling

1. The writer participated in the drilling which was part of the hydrologic research conducted by the Montana Bureau of Mines and Geology. Responsibilities included sample collection, hole logging, and some hole location selection. Sampling and drill log information on individual sites was summarized and submitted to Marvin Miller so that comprehensive site reports could be made and consolidated in one place. These site reports have been submitted to the Department of State Lands by the Montana Bureau of Mines and Geology. The drilling was conducted at eighteen sites in nine counties. Drilling was essentially continuous from October through December, 1974.

Drilling Summary:

	Number of Wells	Number of Drilled Feet Represented
Wells drilled and logged	184	7048
Wells drilled and logged and cased	182	6970
Wells Auger sampled at 2.5 foot intervals		
Frozen	22	1000
Unfrozen	40	1511
Total	62	2511
Wells Core sampled		
Frozen	6	168
Unfrozen	4	102
Total	10	270
Total Wells sampled	72	2781

Total number of samples augered	1004
Total number of samples cored	270
Total number of samples	1274

B. Site selection for intensive investigation.

Three sites were chosen for intensive investigation. The Brickley and Hoagland sites near Rapelje (hereafter called the Brickley-Hoagland site), the Bokma site near Conrad, and the Newby site near Glasgow. The sites were chosen on the basis of similarities and differences in bedrock, surface rock, and topography, as well as the wide geographic distribution of the sites and the number of holes drilled and sampled.

C. Seismic refraction studies.

The power of seismic refraction is that the speed of vibrational waves can be used to infer the type of rock material that exists at a specific depth. Work was done to determine the feasibility of using this technique to determine depth to bedrock and to the water table. Seismic work was done at locations where drill holes were already completed to determine the accuracy of the technique. The seismic method looks discouraging at this time since there is a low degree of correlation between the drill hole data and the seismic data.

D. Investigations of rock and water chemistry.

Nitrate, nitrite, and ammonium were studied first because nitrate is poisonous to humans and animals. The national water quality limit for nitrate is 45 ppm. Saline seeps commonly carry 2-10 times this amount. One source for nitrate is the conversion of organic material to nitrate and the leaching of this ion below the root zone upon cultivation of native sod. The Brickley-Hoagland site is the only site which allows comparison between native sod and cultivated land. A study was made of the nitrate in the ground water and the nitrate distribution in the holes at this site. During the development of the analytical procedure, analyses were performed on a few samples from the Flesch site near Shelby, the Skari site near

Chester, the Newby site near Glasgow, and Hansen site near Chinook. Water analyses were also performed for nitrate at the Bokma site, the Newby site, the Gettle-Jones site near Power, and the Anderson site near Conrad. Bicarbonate, specific conductance and pH were also analyzed at the wells where water quality work was done. Extraction and analytic procedures were studied for the other major ions, but no detailed data is available on these ions.

E. Mineralogic Studies

Mineralogic determinations were made on several salts and on minerals in the till in the Fort Benton area.

F. Bibliography

A computerized bibliography was begun for saline seep and related topics. This work has been abandoned because of the large amounts of time needed to type its references.

G. Extensive investigation of saline seep

Maps of saline seep, geology, land use, and precipitation were compared in a search for inter-relationships.

IV. Summary of Results and Conclusions.

A. Water Quality at the Brickley-Hoagland Site.

The bicarbonate levels in the water appear to be the same both below native sod and cultivated land. The specific conductance of the ground water increases from the recharge to the discharge area both below the native sod and the cultivated land. The increase in specific conductance suggests that the fundamental process operating to introduce ions to the water, operates both under the sod and cultivated land but that the rate of the process is different. The difference in rate may be related to moisture levels. Below the sod the water content is generally less than 10% of the Brickley-Hoagland site while below crop fallow land it is generally more than 10%. Further study should confirm or reject this preliminary conclusion. The pH of the water in the wells is about 7.3, while the pH of a soil-water slurry in the holes is about 8.3. Several possible explanations for this are being considered.

Water quality studies showed that there is no nitrate in ground water below native sod at the Brickley site but that there is 90-170 ppm nitrate below the crop-fallowed land at the Hoagland site. The nitrate values appear to be higher in the spring than in the winter. A more comprehensive and continuous sampling program would help to substantiate this trend.

B. Nitrate and ammonium in the rock profile at the Brickley-Hoagland site.

The nitrate in the rock profile is lower below native sod than below the cultivated land at the Brickley-Hoagland site. The nitrate profiles generally show a maximum near the surface, with the values dropping to a very low level by the time the bedrock is reached. The excess nitrate in the profile below the cultivated land is a minimum of 4 times that which could be produced by leaching all the fertilizer ever applied as nitrate. Therefore, fertilizer does not appear to be the major source of the nitrate. Ammonium was found at the bottom of some of the holes. Although this ammonium might conceivably be converted to nitrate and become a source for nitrate, the depth to ammonium does not appear to be greater below cultivated land than below the sod. This conslusion is very tentative, to further test it, more holes a minimum of 60 feet deep and a minimum of 15 feet into shale would be needed. The absence of nitrate at the bottom of the hole plus the difficulty of drilling in shale indicates that such drilling is not warranted now.

The nitrate source cannot be human or animal waste because there are no concentrated sources for the waste near the cultivated Hoagland site. Fertilizer can be rejected as a source because the nitrate levels in the profile are 4-24 times greater than all the fertilizer nitrate ever added to the system. The high nitrate levels near the surface rather than near bedrock indicate that the bedrock is not the source.

The probable source of the nitrate is the conversion of organic material in the native sod to nitrate upon cultivation. In general, cultivation increases the aeration and moisture regime so that microorganisms can work more effectively to convert organic matter to nitrate. Since water moves through the profile below the root zone after cultivation, nitrate is carried below the root zone too. As the microorganisms use up all the organic material they become stressed, and do not destroy as much organic material or produce as much nitrate. Finally a balance is reached between the amount of organic nitrogen produced by the plants, the amount of organic material used by the microorganisms in the production of nitrate, and the amount of nitrate used by the plants before it is leached from the profile. The level of total organic nitrogen below cultivated land is often lower than below a native sod. Although one would think that most of the nitrate produced by cultivation would have been leached out of the system in the 65 years since cultivation began, the data indicate that this is not the case. Preliminary results indicate a rate of leaching of about 90 pounds of nitrate per acre per year. If this leaching rate proves to be correct, and if it is linear, then it may be another 30 or more years before the nitrate is leached out. During this time, the nitrate level in the water will be three or more times the recommended national water quality standard.

This is particularly alarming when one realizes that young animals and children are particularly susceptible to nitrate poisoning.

C. Nitrate levels at other sites.

Analyses of nitrate at other sites indicate that the nitrate problem is widespread. The nitrate levels in the ground water at the Bokma, Anderson, and Brinkman sites are similar to those at the Brickley-Hoagland site. At the Newby and Gettle-Jones sites the nitrate levels in the ground water are slightly below the national water quality standard. At the Flesch site the nitrate levels in the ground water are extremely high. A comparison of the nitrate levels in the rock profile below the Flesch site and the Skari site indicate the possibility that the Skari site may also have a serious nitrate problem.

D. Discussion of the nitrate problem.

On the basis of the results at the Brickley-Hoagland site, the source of the nitrate is tentatively assigned to cultivation of native sod. This does not preclude a bedrock source for nitrate particularly in areas where nitrate levels are very high, or a fertilizer source particularly in areas which have high permeability such as sandy soil.

Research is warranted on cultivation methods which eliminate or reduce rapid conversion of organic material to nitrate. This research would apply particularly to areas in which native sod is being broken up. The potential dangers of nitrate production by cultivation should be monitored in detail in areas where scalping and furrowing are being applied to native sod to improve over-grazed range (for example the Rohde site). Surges of nitrate in the ground water may be initiated on improved range. If scalping is done every 10 years, then a new surge of nitrate may be initiated with each treatment.

In areas where water is collected for stock use (or human consumption), farmers should be aware that evaporative and freeze concentration of the water can raise marginal nitrate levels to a poisonous level. A simple semiquantitative nitrate test is needed which can be used by farmers on a routine basis. Such a test could provide a danger signal as nitrate levels rise.

Alfalfa may help reduce the nitrate levels in the profile to depths as great as 20 feet. Research is needed, however, to determine if cultivation of the alfalfa to prepare for a new crop produces a nitrate problem of lesser, equal or greater magnitude than before the alfalfa was introduced. If water use rates are low and there is a nitrate problem, alfalfa planted near the water source might help reduce the danger. More research is needed on this aspect of nitrate control.

If humans (especially infants) are drinking high nitrate water, attention should be paid to the possibility that Vitamin C aids in the prevention or cure of nitrate poisoning (methemoglobinemia). If possible, water that does not contain nitrate should be found and used. This may require deep drilling, hauling water, or possibly purification of the water by reduction of the nitrate to a gas. If reduction is employed, particular care should be taken to be sure that nitrite is not produced. Nitrite is more poisonous than nitrate.

Demographic studies of the possible effects of nitrate poisoning in Montana might provide more insight into the nature of the problem. Long range nitrate monitoring may also prove helpful in determining if the nitrate problem is getting worse, staying constant, or slowly subsiding.

More research is also needed to determine if nitrate production is balanced by nitrate use by plants in the cultivated areas. I have assumed that such a balance is present. A long term study should be made using nitrogen isotopes and detailed nitrogen balance concepts to test the hypothesis. If there is not a balance, then the leaching rates are too slow, and the duration of the problem may be much longer than anticipated.

The compound mercury chloride should not be used as a preservative for water which is to be analyzed for nitrate. A 55% reduction in nitrate occurs when this bacterial inhibitor is used. The preservative sulfuric acid was found to have no beneficial effect on nitrate values in the few samples compared to untreated samples. More study is warranted on preservation of samples for nitrogen analyses.

E. Total Ionic Load

There are severe problems with any technique used to determine the total ionic load (salt load), and exchangeable cations. The best procedure appears to be total leaching with potassium acetate buffered to a pH of 8.4 or more coupled with cation exchange capacity determinations. Only a very general approximation of the kinds and amounts of cations on exchange sites will ever be possible.

F. Mineralogical Analyses

Forty-seven x-ray diffraction analyses were completed on seep related salts and clays. The following phases were identified.

1. Calcite -- $CaCO_3$
2, Gypsum -- $CaSO_4 \cdot 5H_2O$
3. Thenardite -- Na_2SO_4
4. Loweite -- $Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$
5. Jarosite -- $KFe_3(SO_4)_2(OH)_6$
6. Smectite -- A clay mineral
7. Illite -- A clay mineral
8. Kaolinite -- A clay mineral

G. Extensive Investigation of Saline Seep

The maps of saline seep and geology appear to show no correlation. This lack of correlation was somewhat surprising for river deposited Flaxville gravel and Quaternary alluvium. More detailed examination of the relationships between saline seep and geology in these apparently anomalous areas will be made.

Saline seep does appear to be highly correlated with land use. The details of the correlation are difficult to establish, however, because of the inaccuracies of the land use maps and the seep maps and the scale of the maps used. The next step in delineating areas of potential seep should be to compare areas which are cultivated and do not have seep with those that are cultivated and do have seep. A map of potential areas for study was made. More drill holes may be needed in this study. If the areas are chosen along primary highways, the Montana Highway Department core library may be of help.

V. Difficulties

Only minor difficulties were encountered. The Montana Highway Department core library is difficult to use because it is organized by project number rather than by easily used geographic coordinates. There is a general lack of paired seep and sod sites as well as sites which are cultivated but don't have seep. If future drilling is done, some consideration should be given to such pairing. The extraction procedures have proven problematic, but work is progressing in this area. There seems to be a scarcity of detailed information on land use in the state. This lack of data plus the small sizes of the maps needed to make the study manageable have caused some problems for the extensive study. By going to carefully selected regions to study the details, many of the problems will probably be overcome.

VI. Future Plans.

This study is being continued under the support of a Water Resources Research Allotment Grant. A limited study of the organic nitrogen levels at the Brickley-Hoagland site will be made to test the conclusions about the source and rate of movement of the nitrate. Two more holes will be analysed to study the nitrate and ammonium distribution, H4 and B3. These holes are in areas of seepage. The nitrogen research will then be phased out, and work will turn toward other ions, and mineralogy. Work will also continue on the comparison of areas that have saline seep with cultivated areas that do not. The objectives of the research remain the same as the work continues.

VII. Project Expenditures.

Personal Expenditures	$4,519
Capital Equipment	537
Travel	1,816
Other	1,136
Total	$8,008

This list of expenditures represents what has cleared the Business Office as of July 22, 1975.

TECHNICAL APPENDIX

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I. Objectives

A. An intensive study is being conducted on three sites which have saline seep in an effort to explain the process by which ground water becomes saline.

1. Determinations are being made of the total amount and distribution of the major ions in the soil and surface rock available for delivery into the ground water system. The major ions in seep water are sodium, magnesium, calcium, sulfate, and nitrate.
2. Investigations of the mineralogy and chemistry of the systems as well as the geologic origins of the ions are being made to identify the process which delivers the ions to the water.
3. A model of the process by which the water becomes salty is being developed using mineralogic, chemical, and geologic data from this study and the hydrologic and water quality data collected by the Montana Bureau of Mines and Geology.

B. Extensive investigation of saline seep is being conducted to develop criteria for prediction of where saline seep is most likely to occur or be most severe, and to produce a map of where those locations are in Montana. The criteria being investigated are mineralogy, chemistry, source of the ions, hydrology, and land use.

II. Activities and Results

A. Drilling

The writer participated in the drilling which was part of the hydrologic research, conducted by the Montana Bureau of Mines and Geology. Responsibilities included sample collection, hole logging, and some hole location selection. Sampling and drill log information on individual sites was summarized and submitted to Marvin Miller so that comprehensive site reports could be made and consolidated in one place. These site reports have been submitted to the Department of State Lands by the Montana Bureau of Mines and Geology, but a generalized summary is enclosed in this report. All holes but two were cased with three or four inch pipe. A minimum of 10 feet of perforated pipe was used at the bottom of the holes and the hole was flushed and gravel packed to within four feet of the surface. Well-head elevations still need to be determined to provide topographic and stratigraphic control.

Drilling Summary:

Drilling was conducted at eighteen sites in nine counties. Drilling was essentially continuous from October through December, 1974.

	Number of Wells	Number of Drilled Feet Represented
Wells drilled and logged	184	7048
Wells drilled and logged and cased	182	6970
Wells Auger sampled at 2.5 foot intervals		
Frozen	22	1000
Unfrozen	40	1511
Total	62	2511
Wells Core sampled		
Frozen	6	168
Unfrozen	4	102
Total	10	270
Total Wells Sampled	72	2781

Total number of samples augered	1004
Total number of samples cored	270
Total number os samples	1274

B. Site selection for intensive investigation.

Three sites were selected for intensive investigation. The Brickley and Hoagland sites near Rapelje (hereafter called the Brickley-Hoagland site) were selected because one site is on native sod which has never been plowed and one site is farmed under the crop-fallow system. The farmed site has saline seep. Thus, some idea of the effects of farming can be gained by comparing the two.

An Eagle Sandstone escarpment stands above a more gently sloping farmed area with colluvium over Colorado shale. The gentle slope has a saline seep at its base. The Brickley-Hoagland site is unglaciated.

The Bokma site near Conrad is covered by glacial till, but has the same bedrock and general topographic relations as the Brickley-Hoagland site. Thus, comparison is provided between seeps on unglaciated colluvium and glacial fill.

The Newby site near Glasgow was chosen because the surface material is the same as at Bokma's but the bedrock is Bearpaw shale rather than Colorado shale.

These sites were also chosen because more comprehensive drilling and sampling were completed on them. The sites are located in widely separated areas of Montana and provide a reasonable cross-section of the saline seep problem in the state.

C. Investigations of chemistry

1. Ammonium nitrate and nitrite

a. Problem and hypotheses

One aspect of saline seep which has generated concern is the high level of nitrate (NO_3) in the seep waters. Nitrate is known to produce methemaglobinemia in the blood of humans and animals

(Viets, et al., 1971; Tomlinson, 1974). Methemoglobinemia results in the inability of blood to carry oxygen. The result is anoxia, a kind of suffocation. This disease strikes young children and animals more severely than adults (Viets, et al., 1971). Cattle have died drinking seep water (Lester Flesch, Shelby, MT; Larry Barber, Denton, MT, personal communications, 1974). Although autopsies have not been performed on the cattle, nitrate poisoning is suspected. In these cases the poisoning may have resulted from evaporative concentration of nitrate bearing water to toxic levels. Fortunately, no human deaths have been reported. In the Denton-Coffee Creek area, people are drinking water with 140 ppm nitrate (Ron Brinkman, Coffee Creek, MT, personal communication, 1974). The recommended United States water quality limit for nitrate is 45 ppm (Bahls, et al., 1973, McKee, 1963).

For the above reasons, a study of the process of nitrate production in saline seeps was initiated. There are several possible sources for the nitrate. These include fertilizer, animal and human waste, nitrogen disequilibration upon tillage of native sod, and bedrock nitrate (Viets, et al., 1971; Reinhorn, et al., 1974; Kreitler, et al., 1975; Power, et al., 1974).

The high nitrate areas are not restricted to feel lots or sewage systems. Therefore, animal waste is probably not generally the source of the problem. Talks with farmers in Broadview at a meeting in February, indicated that fertilization was sufficiently rare that a source other than fertilizer should be considered. Nitrogen cyle disequilibration of some sort seemed to be the key (Reinhorn, etal., 1974; Kreitler, et al., 1975). Generally, cultivation of native sod increases the aeration and moisture content of the soil. As a result, more organic matter than usual is converted to nitrate by microorganisms. Nitrate is produced faster than the crops can use it, so nitrate is leached below the root zone. As time passes, the level of organic material below the cultivated land is depleted and the microorganisms are stressed until the amount of nitrate produced is used by the plants. Nitrate production after cultivation is fast and reaches equilibrium again quickly (Reinhorn, et al., 1974; Kreitler, et al., 1975; Swaby, et al., 1963; Jenkinson, 1963). Since 65-75 years have passed since cultivation began in much of eastern Montana, it seemed unlikely that much excess nitrate due to cultivation would be left. A slower man-induced natural nitrate release process was sought.

Ammonium (NH_4) on exchange sites in bedrock, if exposed to increased aeration and moisture can be converted to nitrate by nitrifying bacteria (Power, et al., 1974). If cultivation indirectly affects deep layers (on the order of 10 m) and the process of conversion is slow due to marginal living conditions for nitrifying microorganisms, then ammonium native to the bedrock might be the source of the nitrate problem. Furthermore, the bedrock itself may have local nitrate highs (Viets, et al., 1971).

To test these hypotheses, the distribution of inorganic nitrate and ammonium were determined with depth on native sod and cultivated land. If the depth to ammonium is greater under cultivated land than under sod, then a process of increased aeration and moisture leading to conversion of ammonium to nitrate might be called on as a nitrate source. If these depth relationships do not hold, bedrock ammonium can be rejected as a source. If the bedrock contains native nitrate, then the nitrate level should be high in the bedrock. If cultivation of native sod or fertilization were the source of the nitrate, a leaching front might be present with high nitrate near the surface and little nitrate in unplowed areas.

b. Site selection for nitrogen analyses

To test the above hypotheses, one needs to study cultivated and uncultivated paired sites. In Paleocene shale, under sod, the ammonium to nitrate transformation takes place above 10 m (33 ft) (Power, et al., 1974). Thus the cultivated sites were to be studied relative to the 10 m datum. As will be seen, this datum is not valid.

There are only two sets of paired sites with sod and cultivated land. The Brickley-Hoagland pair near Rapelje and the Newby-Rohde pair in Valley county. The glacial deposits at the Newby site are relatively pebble free, while at Rohde's the cobbles and pebbles are numerous. Accurate sampling is almost impossible at Rohde's because augered material is apparently driven into the formation rather than moving up the drill string. Coring is impossible at this site and drilling with augers is very hard on equipment due to high abrasion rates. Therefore, the Brickley-Hoagland site is the only paired native sod-cultivated (seeped) site suitable for study.

c. Methods

1) Rock and soil sample analysis

a) Sampling

Two Mobile B-50 drill rigs were used to obtain samples.

Three sample procedures were used. The most accurate was split core sampling. A tube which can be split open was driven into the ground and retrieved. A hole was augered down to where the core was stopped, and a new core was taken. The cores were cut in two with a knife, half the core was saved intact if possible and half the core was bagged to be mixed and frozen. The core is a fairly accurate sample (± 0.5 ft), and contamination from scraping of the side of the hole and mixing due to augering is minimal using the Mobile B-50.

A second method consisted of augering 5 feet and pulling the auger string straight out of the hole with the cable. The material on the exterior of the auger was scraped off to reduce contamination from the side of the hole. The samples taken from the top whorls of the 5 ft auger flight were mixed in one bag, and samples from the bottom whorls of the 5 foot auger flight were mixed in a second bag. Sealed zip lock bags were used to prevent moisture loss. The sample depth precision is not known but is assumed to be of the order of ± 1.25 feet. The amount of contamination from up hole is assumed to be less than 10%. All augered samples drilled with the SCS rig were done in this manner.

When using the Highway Department rig, the drillers preferred not to pull the drill string with the cable. A 5 ft auger length was put on, they augered down 5 feet, and without drilling deeper, the augers were turned until most of the sample was augered to the surface. A grab sample from the beginning and end of the augering was collected. Depth accuracy for sampling is estimated to be ± 3 feet. The degree of contamination cannot be evaluated, but is probably higher than that for pulling the augers out with a cable every 5 feet. An estimate of 10% contamination is assumed because changes in lithology could be seen as moderately clean breaks.

At Columbus, the county extension agent, Chuck Egan, made a freezer available so samples were frozen within 12 hours. In some cases, the samples were rethawed for 2 days in transit and were then refrozen at -18°C. All frozen samples were stored at -18°C. Without freezing, the form of the nitrogen and its total quantity could change due to the activity of microorganisms.

Apparatus and procedure for analysis were not ready until March, so the samples remained unanalyzed for 6 months. Freezing has been shown to effectively stop nitrogen conversions for this long (Power, et al., 1974).

b) Sample treatment

Duplicate analyses of wet and dry subsamples were performed. The samples used were from the Skari site so that standardization of procedure could be achieved without using up all of any one Brickley or Hoagland sample. The results are shown in Table 1. Although the number of analyses is small, the results tend to support the possibility that ammonium levels depend on the treatment. To prevent irreversible drying effects, the samples were analysed wet.

c) Extraction procedure

The nitrate and ammonium were extracted simultaneously with 100 ml of 2N KCl following a procedure modified from Bremner (1965) and Bremner and Keeney (1966). Twenty samples at a time were prepared over a three-day period.

Table 1a. Replicate extractions for wet and dry material

	Wet		Dry	
	NH_4 ppm	NO_3 ppm	NH_4 ppm	NO_3 ppm
SK2 13-15				
Mean (2 samples)	5.6	256.0	11.45	265.5
Deviation from mean	.65	13.5	.65	.9
% error	11.6%	5.3%	5.7%	0.3%
SK2 48-50				
Mean (2 samples)	136.0	47.8	93.4	47.1
Deviation from mean	.1	4.0	1.1	6.8
% error	.1%	8.3%	1.2%	14.5%

Table 1b. Wet compared to dry samples

	NH_4 ppm	NO_3 ppm
SK2 13-15		
Deviation wet - dry	-5.85	-9.5
% error relative to wet	103.6%	3.7%
SK2 48-50		
Deviation wet - dry	+42.6	- .7
% error relative to wet	31.3%	1.46%

The first day, sample aliquots were weighed (wet) and moisture determinations begun. The sample was quartered on a piece of waxed paper. If the sample was very wet, its frozen condition made quartering and sub-sampling difficult. These samples were broken into at least 4 parts by light grinding with an iron mortar and pestle and then sampled. A 15 ± 3 g wet sub-sample was taken with contributions from each of the quarters, was weighed to 3 decimals, and placed in a 50 ml plastic centrifuge tube. A second sub-sample was taken and placed in an oven at 70°C ± 3°C. This sample was reweighed after 3 days of drying and the moisture percent, dry weight and volume of liquid in the sample were calculated from the data. A temperature of 70° was chosen because it is the optimum drying temperature for preservation of the sample for total N analysis. The centrifuge tubes were covered with plastic wrap and placed in a refrigerator freezer at 0°C.

On the second day, 100 ml of 2N KCl was measured in a volumetric flask. This flask was then used as a wash bottle and about 20 ml of the KCl solution was put in the centrifuge tube. The sample was disaggregated using a Bronwill Biosonik III disaggregator at an intensity of 50 for 2 minutes. The material remaining on the disaggregator probe was washed into the centrifuge tube and the sample was then washed into a 250 ml polyethelene bottle and capped. The disaggregation procedure was performed to help insure that the entire sample came in contact with the extraction solution. The disaggration was effective in most cases. Replicate analyses of samples which did not appear to disaggrate completely showed values within the precision of the Kjeldahl analysis. The samples were stored overnight at 7°C.

On the third day, the samples were removed from the refrigerator and placed on a shaker table for 1 hour. The samples were then centrifuged at 1500 rpm for 5 minutes to clarify the solution.

d) Analytic procedure

The samples were then analyzed using a semi-micro Kjeldahl apparatus following Bremner (1965). Ammonium was analyzed using distillation with MgO. Nitrate and nitrite were analyzed together using distillation with Devarda's alloy because quantitative recovery of nitrite using sulfamic acid was not achieved on standards. The reason for the problems with nitrite are not clear. All values reported here as nitrate are really nitrate plus nitrite. Since nitrite is also a poison, no important error was felt to be introduced. This procedure analyzes only the inorganic ammonium, nitrate and nitrite, not organic forms of nitrogen (Bremner, et al., 1966).

The ammonium is assumed to be exchangeable; the nitrate plus nitrite are assumed to be soluble. This assumption is necessary since the samples were not washed with deionized water before the extraction. Preliminary trials using deionized water washes before KCl extraction showed the nitrate to be water leachable and the ammonium to be K extractable.

To test whether ammonium might be irreversibly locked on exchange sites by the use of potassium as an exchange ion (Nommik, 1965), the samples were run using 2N KCl and replicated using 2N $BaCl_2$ (Table 2). The results indicate no increase in ammonium with the $BaCl_2$ treatment except possibly Sk4. Since the microburett was not available at the time of these analyses, the error

Table 2. Replicate analyses using 2N KCl and 2N BaCl$_2$

		KCl NH$_4$	BaCl$_2$ NH$_4$	Deviation K-Ba NH$_4$	KCl NO$_3$	BaCl$_2$ NO$_3$	K-Ba NO$_3$
RN1	38-42	6.19	11.73	-5.54	12.03	4.25	7.78
RN1	48-52	27.80	26.81	0.99	-	9.29	-9.29
H 3	34-36.8	2.58	1.42	1.16	49.12	48.68	0.44
H 3	39-45	4.25	-	4.25	61.5	42.92	18.58
SK4	53-55	23.80	30.42	-6.62	3.10	29.20	-26.10
SK4	57-59	14.43	28.49	-14.06	-	30.09	-30.09
SK2	45-48	146.50	135.34	11.16	91.5	30.09	61.41
KH5	55-58	16.10	14.18	1.92	-	6.64	-6.64
			mean	-6.74		mean	+16.09

is within the precision of the method. The high dispersion of the nitrate analyses remains unexplained.

e) Reproducibility and accuracy

Duplicate analyses were performed both on the same extract of a single sub-sample (within sample) and on extracts of different sub-samples (between sample). The data from these analyses are presented in Table 3. The analytic error for ammonium is of the order of ± 0.5 micrograms per gram and for nitrate is of the order of ± 4 micrograms per gram.

Standards were made following Bremner (1965). When the standards were diluted to 5 ppm ammonium and nitrate, a 10% error was obtained.

2) Water analyses

Water analyses for nitrate plus nitrite and ammonium were performed using kjelkahl distillation with MgO and Devarda's alloy respectively (Bremner, 1965).

Several preservative schemes were examined to prevent changes and losses in the nitrogen species during the time between sampling and analysis. Originally, $HgCl_2$ was tried (Brown et al., 1970, p. 17). This procedure was abandoned because a 55% loss of nitrate plus nitrite was observed in the treated sample when standards containing 1500 ppm NO_3+NO_2 were made and analysed on the same day with and without the bacterial inhibitor. No change in the ammonium values were detected within the error of the procedure. Presumably, a complex is forming between the mercury and the anions.

A sulfuric acid treatment was also tried as a preservative (EPA 625-/6-74-003). One ml of concentrated H_2SO_4 was added to

Table 3. Reproducibility Results

A. Analyses of the same extract from a subsample of rock material

		µg/g NH_4	µg/g NH_4	Deviation from mean	µg/g NO_3	µg/g NO_3	Deviation from mean	Moist %	Moist %	Deviation from mean
B5	13-15	0.71	1.07	0.18	14.66	14.66	0			
	26-28	1.79	2.77	0.45	13.50	15.46	-1.96			
	48-53	7.11	7.89	.39	5.42	-4.07	+9.49			
H3	0-3	4.47	4.15	.16	193.04	199.63	6.59			
H7	20-23	2.45	0.90	+1.55	0.00	-3.08	+3.08			
	32-33	2.54	1.45	+1.09	8.73	14.97	-6.24			
H3	34-36.8	2.58	2.69	-0.11	49.12	43.14	+5.98	23.10	20.878	1.11
			mean	0.36		mean	+2.38			

B. Analysis of extracts from different subsamples of rock material

		µg/g NH_4	µg/g NH_4	Deviation from mean	µg/g NO_3	µg/g NO_3	Deviation from mean	Moist %	Moist %	Deviation from mean
38	16.5-18	3.39	2.76	.31	7.40	8.53	-1.13	7.84	7.36	0.48
	25	1.40	2.01	.305	3.60	3.45	+0.15	5.59	6.15	.55
Wet SK2	13.5	6.3	5.0	0.65	242.5	269.5	-27.00			
	48-50	136.1	135.9	0.1	51.8	43.8	8.00	31.05	30.25	0.80
Dry SK2	13.5	12.1	10.8	.65	266.4	264.6	0.90			
	48-50	94.7	92.5	1.1	40.3	54.0	6.85			
			mean	0.52		mean	+4.32			

250 ml of water. The pH of the water was lowered below 2 in all samples to which this treatment was applied. A sample with no acid was also collected. Both samples were analysed within a week. Table 4 provides data comparing treated and untreated samples. If one takes the analytic error as 0.5 ppm for ammonium and 4 ppm for nitrate plus nitrite, the difference between acidified and untreated samples is not detectable. The data indicate that if the samples are analysed within a week of collection, no advantage is gained by acidification. Data reported hereafter is for untreated samples.

Bicarbonate analyses and pH determinations were performed following Brown et al (1970). Bicarbonate was titrated both in the field at the Bokma site and in the lab. Table 5 presents the data. There is no significant difference between field and laboratory results.

The pH values appear to vary ± 0.2 units between the lab and the field. There does not appear to be a systematic tendency for the laboratory value to go up or down relative to the value in the field.

Specific conductance was measured on some of the samples. More of this work would have been done, but incorrect information on the conductivity probe from the manufacturer lead to confusion and a long delay in obtaining the correct probe. The problem has been resolved and the correct probe will arrive soon. Some conductivities were obtained through the cooperation of Marv Miller. The conductivities were temperature corrected to 20°C using Richards, et al., 1954, P. 90.

Table 4. Comparison of NH_4 & NO_3 in acidified and untreated water samples

	Acidified NH_4	Plain NH_4	Deviation NH_4	Acidified NO_3	Plain NO_3	Deviation NO_3
B04	1.17	.54	+ .63	79.1	89.5	-10.4
B019	3.07	3.29	-0.22	3.72	1.85	+ 1.87
B022	0.00	0.00	+0.00	47.39	43.36	+ 4.03
B023	1.68	1.71	-0.03	36.86	37.6	- 0.74
BO_{spring}	1.08	1.26	-0.18	3.40	2.47	+ 0.93
LA2	1.08	1.39	-0.31	42.74	64.25	-21.51
LA8	1.13	1.26	-0.13	62.87	73.89	-11.02
GJ2	1.48	1.53	-0.15	4.03	3.23	+ 0.80
GJ5	1.44	1.31	+ .13	22.30	23.67	- 1.37
RN9	-	-		39.95	43.36	- 3.41
5μg Std.	4.27	4.55	- .28	4.23	4.58	- 0.35
5-day-old 5μg Std.	4.51	4.62	- .11	3.85	4.51	- 0.66
	Mean		-.058			-3.34

Table 5. Comparison of field and lab bicarbonate and PH determinations on water at the Bokma site

A HCO3

	Field	Lab	Field-lab
B04	639	621	+18
B019	358	363	-5
B022	947	943	+4
B023	438	434	+4

B pH

	Field	Lab	Field-lab
B04	7.13	7.10	+.03
B019	7.38	7.10	+.28
B022	7.37	7.59	-.22
B023	7.51	7.60	-.09

d. Results and Discussion

1. Brickley-Hoagland site

a) Location

The Brickley and Hoagland sites are located in Stillwater County near Rapelje. A generalized sketch map is provided to help locate the holes (Figure 1). A copy of the site reports is included below. The Hoagland holes have the prefix H, the Brickley holes have the prefix B. The holes are numbered in order of drilling. This map is not to scale but displays the general relationships.

The two sites are topographically similar. The Brickley holes drilled in cultivated land were in an area of more rolling topography. Therefore, the Brickley-Hoagland pair was chosen for study.

b) Geology

Eagle sandstone forms the escarpment north of the study area (Figure 1). The basin below the escarpment is underlain by Colorado shale. There is a slope off the escarpment into the basin composed of silty clay loam derived from the escarpment and washed toward the basin (colluvium). The colluvium has gypsum and calcite in it. Some units are more clay rich than others.

c) Land History

The Brickley site is covered with native sod. Mr. Phil Brickley has farmed the area for 46 years and believes the ground has never been broken. The land is used as pasture for cattle and no treatments have been used to enhance grass production.

The Hoagland site was first farmed in 1907 according to Mr.

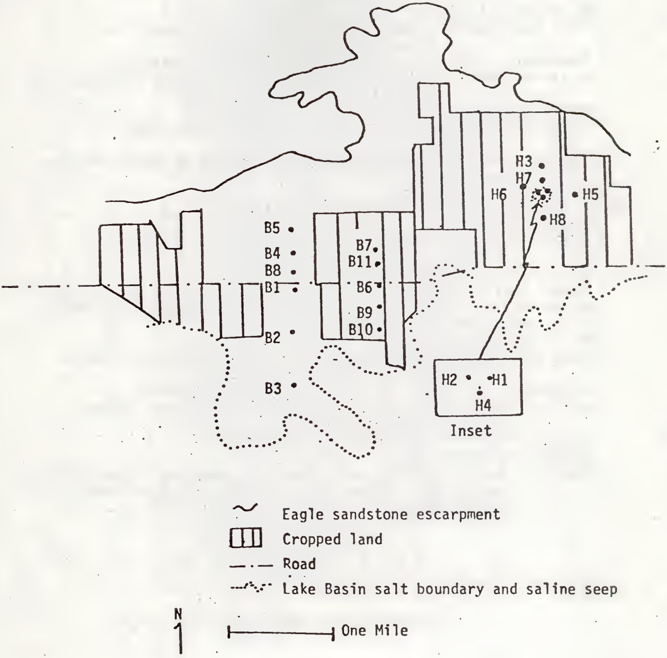


Figure 1. Sketch map of Brickley-Hoagland site

Site 1. Rapelje region - Hoagland area
County: Stillwater
Location: T. 4 N., R. 21 E., sec. 32
Research Team: Miller, Custer, Ferguson, Krall, and Brown
Owner: Bill Hoagland
No. of Holes Drilled: 8 (all cased, flushed, and gravel packed)
No. of Holes Sampled from Auger: 3
No. of Holes Cored: 2
Other Data Obtained: Water levels taken: SC, Eh, and pH measured; resistivity profiles run
Topography: Internally drained basin (unglaciated area)
Surficial Material: Colluvium (derived from Eagle and Colorado Formations)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Principally alternate crop-fallow area, some alfalfa
Remarks: This site had previously been selected by Hayden, Ferguson and Jim Krall

Site 2. Rapelje region - Brickley area
County: Stillwater
Location: T. 4 N., R. 20 E., sec. 35, 36
T. 3 N., R. 20 E., sec. 12
Research Team: Miller and Custer
Owner: Phil Brickley
No. of Holes Drilled: 11 (all cased, flushed, and gravel packed)
No. of Holes Sampled from Auger: 6
No. of Holes Cored: 2
Other Data: Water levels taken; SC and pH measured; resistivity and seismic-refraction profiles run
Topography: Internally drained basin (unglaciated area)
Surficial Material: Colluvium (derived from Eagle and Colorado Formations)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Native sod
Remarks: This site should be excellent for comparing cropped versus sod systems. Sod area was very dry relative to nearby cropped area.

Hoagland. Today the site is an alternate crop-fallow wheat farm. Summer fallow was begun between 1920 and 1925 (Bill Hoagland, personal communication). Bill Hoagland said he began fertilizing with 18-48-0 (N,P,K) at the rate of 60 pounds of fertilizer per acre on alternate strips ten years ago. The cultivated land north of B3 has received no N fertilizer, but recently P and K have been added (Jim Hoagland, personal communication).

There is extensive salinity below both sites, but this 'natural' salinity occurs much farther away from the escarpment below the native sod than it does below the farmed land.

d) Moisture Content

Moisture determinations were performed on samples from 9 holes. The data for B5, B8, H3 and H7 are presented in Figures 2-5. Table 6 has the moisture data for the other holes. Holes S4 and S3 are from the Schneidt site. No further discussion of the Schneidt data is warranted at this time.

In general, the Brickley site (native sod) is drier than the Hoagland site (cultivated). If 10% moisture is taken as a cut-off, the sod holes tend to be at or below this level, and the cultivated sites tend to be above this level. Although the native plants use water more efficiently than crops, the higher moisture contents near the bottom of B1 and B5, and the presence of water in holes in the sod, indicate that some water gets below the root zone. The path the water takes to get to the colluvium-shale contact is not precisely known. B3 is anomalously wet because of its proximity to the bottom of Lake Basin. There are native plants on the fence row at H3 which probably behave like

Table 6. Moisture Data from the Rapelje Area

Percent Moisture		Depth
7.915	B1	0-1.5
8.152		1.5-3
10.666		3-5
10.629		5-8
10.278		8-13
14.021		13-15
24.838		15-16
17.275		16-18
5.284		18-23
12.918	B3	0-1
16.565		1-3
17.373		3-7
25.072		7.5-8
22.655		7.5-8
22.108		8-10
22.822		10-13
24.077		13-16
22.735		16-18
19.356		18-20
18.176		23-26
20.164		26-28
21.196		28-36
23.453		36-39
21.848		39-41
23.502	H4	4-1.8
23.495		0-1.4
24.343		2.8-5.4
23.890		5.4-8
24.359		8-9.8
19.606		10-12
15.680		12-13.4
21.688		13.4-15
21.706		16-18
19.764		~23
20.890		18-20
10.356	S4	0-6
18.074		0-31
19.827		3-5
20.053		5-6
33.609		6-8
25.307		8-10
23.491		10-12
20.462		12-13

Table 6. (continued)

Percent Moisture		Depth
14.325		13-18
12.302		18-19
28.221		19-20
31.270		20-23
33.359		23-25
25.944		25-28
28.055		28-30
24.513		30-33
26.726		33-35
19.429		35-40
15.276		40-45
4.579	S3	3-3
10.965		5-8
12.295		8-10
15.447		10-12
7.063		12-16
4.907		16-18
5.155		18-21
6.657		21-23
9.157		23-25
8.275		25-28
8.234		28-30

Figure 2. Nitrate plus nitrate, ammonium, and moisture content profiles for B5

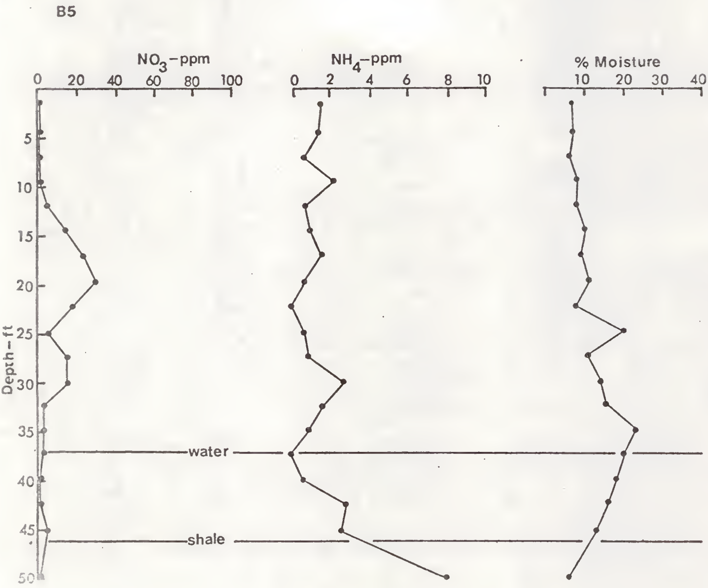


Figure 3. Nitrate plus nitrite, ammonium, and moisture content profiles for B8

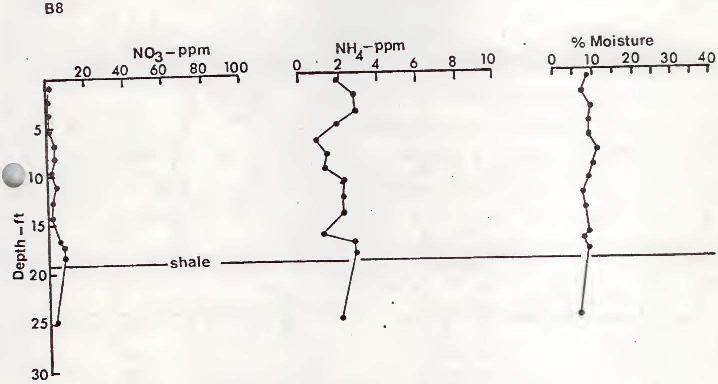


Figure 4. Nitrate plus nitrite, ammonium, and moisture content profiles for H3

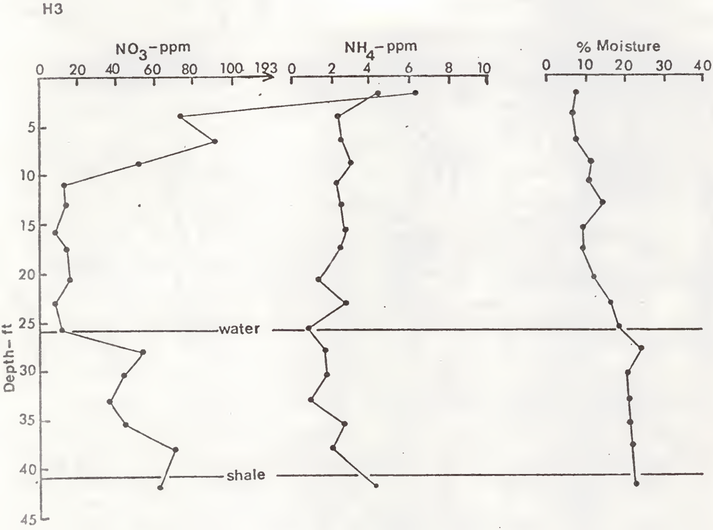
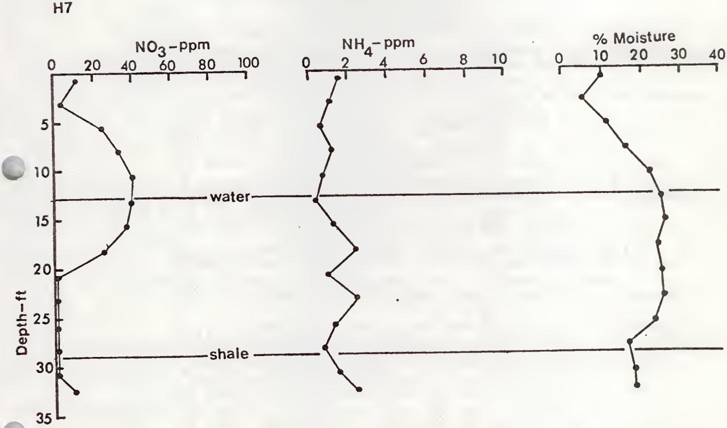


Figure 5. Nitrate plus nitrite, ammonium, and moisture content profiles for H7



those on the native sod and keep the upper part of the profile dry. The wet lower profile at H3 reflects water movement past the fence row below the root zone. This is a similar situation of B6 which was dry when drilled on a fence row surrounded by cultivated land, but later filled with water.

Shale was encountered in all holes for which moisture determinations were made (Figures 2-5). The shale, when sampled before free water entered the hole, has a moisture content of around 6%.

The higher moisture percentages for shale in B3, H3, H7, H4 may be due to the free water encountered in the holes during drilling. With the exception of B3 and H4 which are discharge areas, field notes indicate that the shale appeared to be drier. These tendencies, plus the trend to lower water content with depth indicate that the Colorado shale supports a perched water table.

e) pH of the drilled material

The pH of 1:1 rock:water slurries from two holes were analyzed (Table 7). The pH levels are slightly higher at the Hoagland site than at the Brickley site, but values at both tend to be 8.3-8.6. These values are higher than the pH of the water which tends to be 7.3-7.6. A pH of 8.3 is near the pH of water equilibrated with calcium carbonate. There are at least four possible explanations for the large pH discrepancy. 1) The samples were frozen and a large amount of time elapsed between soil sampling and pH determinations. A change in the chemistry of the system might have taken place during the elapsed time. 2) There is a

Table 7. Soil PH taken on a 1:1 slurry

H3		B5	
Depth	pH	Depth	pH
0-3	8.22	0-3	8.72
3-5.4	8.60	3-6	9.18
5.4-7.8	8.65	6-8	8.12
7.8-10	8.80	8-11	8.30
10-12.4	8.95	11.1-13	8.38
12.4-13.8	8.60	13-15	8.43
14.8-16	8.62	18-20	8.32
17-18.2	8.55	20-23	8.30
19.4-21.8	8.50	23-26	8.20
21.8-24	8.37	26-28	8.18
24-26.8	8.40	28-33	8.10
26.8-29	8.41	33-36	8.01
29-31.8	8.47	36-38	8.01
31.8-34	8.40	38-40	8.01
34-36.8	8.33	40-43	8.02
36.9-39	8.29	43-46	7.98
		46-48	7.91
		48-53	8.08

reaction between the water and the Amoco CS 228-61 sewer pipe used to case the holes. To test this possibility, some measurements should be made on the water while the wells are being pumped so that the water is as much like formation water as possible. 3) A 1:1 slurry and saturated soil have different pH's. 4) The water in the system is not in equilibrium with the bulk rock. This could happen if the water in the system moves along channels such as fractures which have a chemistry different from the bulk chemistry of the system. The process of augering the sample would grind up the rock and soil material and expose the water to a chemistry it is not in contact with in situ. If this alternative is correct, many of the ions in the water in the saline seep may be coming from saturation of the entire profile as the water table rises, rather than general leaching during downward percolation. Each time material which was not saturated before becomes saturated, a new increment of salt is dissolved. The implication of this hypothesis is that the salts are being leached from the bottom up as a result of a rising water table rather than from the top down. 5) The pH of the ground up rock material might also represent an abrasion pH caused by grinding during drilling. More detailed studies of the water pH, mineralogy and chemistry need to be made before a definite conclusion can be reached.

f) Water analyses

The water at five wells at the Brickley-Hoagland site was checked in the winter and spring to see if there was an increase in the nitrate levels in the spring. The data is presented in

Table 8. As expected, the ammonium values are low. Any ammonium that is introduced into the ground water system is converted to nitrate. Nitrate values in water below native sod are zero. At H3, the nitrate rose about two-fold in the spring. This rise may be due to increased activity of microorganisms, and/or flushing of nitrate by spring percolation and water table rise. The nitrate level appeared to drop slightly at the seep in the spring. This drop may have been caused by denitrification in the water logged seep soils, by dilution from runoff, or by slow water movement where the nitrate produced or leached has not yet reached the seep.

There is a large variability in the bicarbonate levels in the water for unknown reasons.

An increase in specific conductance corresponds to an increase in salinity. There is a down slope increase in the specific conductance (salinity) in the ground water at both the sod and cultivated sites. The very high conductivity of the water at B3 is probably due to its location near the bottom of Lake Basin where salts have been accumulating for many years. This trend implies that there is little fundamental difference between the gross water chemistry below native sod and cultivated areas. More detailed water quality work is needed to verify this conclusion. This conclusion does not apply to nitrate.

The water temperature at both the Brickley and Hoagland sites is 7-9°C year around. This low temperature is interesting in view of the work of Power, et al (1974) who showed that transformation of the ammonium to nitrate is very slow at these temperatures.

Table 8. Water analyses from the Brickley-Hoagland sites

Collected February 25, run February 27.

	NH_4	NO_3	HCO_3	pH	Sp Cond	Temp °C
B5	0	-1.6	330	7.28	5357	9.8
B1	-.9	-2.9	816	7.10	7530	9.3
H3	+.4	88.5	325	7.52	4518	9.0
H4	-.5	95.8	542	7.31	7341	9.0

Collected June 14, run June 19.

	NH_4	NO_3	HCO_3	pH	Sp Cond	Temp °C
B5	0	0	337	7.3	5335	-
B1	0	0	762	6.98	8543	-
B3	0.2	1.4	762	7.50	12742	-
H3	0	172.1	257	7.30	5198	9.3
H4	0.9	78.0	457	7.23	9474	7.4

g) Ammonium and nitrate distribution with depth

At the Brickley-Hoagland site, four holes (B5, B8, H3, H7) were examined to determine the distribution of ammonium and nitrate below sod and cultivated land. The results are presented graphically in Figures 2-5. When studying these figures, it is important to remember the locations of the holes (Figure 1).

The ammonium values at all sites generally fall at the 2 ppm level with three exceptions. The bottom of the hole at B5 and H3 and the top of the hole at H3. At B3 the ammonium goes from 4 ppm at 33 feet to 12 ppm at 40 feet. Thus the depth to ammonium at the two sites ranges from 35-47 feet, somewhat deeper than the transformation depth of 33 feet in the Fort Union formation (Power, et al., 1974). Although more holes drilled deeper would be desirable, there appears to be no tendency for the ammonium to be deeper below cultivated land than below native sod. If deeper holes were to be drilled, they should be a minimum of 60 feet deep. Such depths would be difficult to achieve because dry Colorado shale is difficult if not impossible to penetrate using the Mobile B-50 and augers. The dryness of this material (approximately 6%) probably precludes the ammonium to nitrate transformation (Power, et al., 1974).

The 4 ppm ammonium values at the top of H3 probably represents the fact that ammonium phosphate is used as a fertilizer.

The nitrate profiles in the holes drilled in sod show levels lower than those in cultivated land. B5 has no nitrate in the water but does have some in the profile. The source of the nitrate and its distribution at B5 are not known, but some hypotheses are open. The maxima in the middle of the profile and hole location in the recharge area indicate a near surface source. The nitrate could come from 2 or more surface sources. 1) Unknown early cultivation could produce nitrate (1900-1907?). This hypothesis seems unlikely in view of the more rugged topography at B5 than at B8 and the relative absence of nitrate at B8. 2) The nitrate could have come from organic material in buried soil profiles not recognized during drilling. 3) The nitrate could have come from nitrogen released by fire or other natural event which allowed conversion and leaching of nitrate on the sod. This hypothesis also suffers because of the lack of nitrate in the profile at B8. The nitrate maxima in B5 do not correspond to high moisture contents and are above the water table and the shale. The two maxima might result from unrecognized buried soil profiles, from changes in porosity and permeability which might lead to a multiple leaching front, or from two episodes of nitrate release separated by a period of no release.

In the holes in the cultivated land the profiles are very different (Figures 4 and 5). In general, the levels of nitrate are higher under cultivated land than under sod. This pattern is expected since the water under cultivated land has nitrate in it. The source for the nitrate in the profile is somewhat speculative. A surface source is indicated by the nitrate highs near the surface. The lack of correlation of nitrate levels with percent water indicates that the nitrate is not controlled entirely by free water. Although the nitrate at 28 feet in H3 might be related to the water table, this relationship may be fortuitous, the nitrate data do not parallel the moisture content data. If the nitrate levels at H3 are related to free water, it is surprising that H3 shows the relationship while H7 which is topographically lower and should be connected to H3 shows no relationship.

The nitrate high in H7 may represent a leaching front. This leaching front may have originated in one of the following ways. 1) Vertical movement of water may carry nitrate down to the water table. The water than moves laterally toward the discharge area and removes the nitrate. This assumes that each leaching phase does not remove all the nitrate above the water table. 2) Nitrate rich capillary water may move up in response to evaporation in dry periods and deposit nitrate as it vaporizes. There may be downward movement of nitrate during wet periods. The nitrate high then represents the point where upward and downward motion of water tend to cancel out. The fact that the water table lies within the nitrate maxima could be explained by a recent rise in the water table.

The highly anomalous nature of the nitrate profile at H3 is probably related to its location on a fence row with native grasses. The extremely high nitrate values near the surface indicate nitrate production with little leaching. The lack of leaching may be caused by the timely use of water by the plants. The nitrate production may be explained by increases in aeration and moisture control due to the immediate proximity of cultivated land.

The lower maxima may be due to lack of leaching and may be comparable to those in B5. The lower maxima may also be due to leaching fronts from earlier leaching phases or to nitrate brought in by the water from the cultivated land north of H3.

The source of the excess nitrate under the cultivated land could be fertilizer or the conversion of organic material to nitrate in response to cultivation. The fertilizer hypothesis can be tested by comparing the amount of nitrogen added as fertilizer since fertilization began with the amount of nitrate in the profile. The amount of nitrate added to the Hoagland site as fertilizer can be calculated using the equation: Fraction N in the fertilizer · pounds/acre of fertilizer · 10/2 · 4.425 pounds of nitrate per pound of nitrogen = pounds of nitrate per acre. The fraction 10/2 represents 10 years of fertilization, fertilizing each strip every other year. This equation makes the severe assumption that all nitrogen added as fertilizer is converted from ammonium to nitrate and is leached below the root zone. Although this is an unlikely assumption, it does provide the upper boundary condition. The lower boundary condition is that no fertilizer nitrate is leached below the root zone. Bill Hoagland has added 238 pounds per acre of nitrate to his fields.

The amount of nitrate in the profile can be calculated by totaling the nitrate in 2 ft thick 1 acre segments over the entire profile. $\sum_{\text{bottom}}^{\text{Top}}$ 2 ft · 43560 sq ft/acre · 28317 cm^3/ft^3· density of the soil (g/cm^3) · xμg NO_3/g · $10^{-6} g/\mu g$ · 2.205 x 10^{-3} pounds/g = pounds of nitrate per acre in the profile. Table 9 shows the results of this calculation for the 4 holes at 3 densities. If one assumes the low density (Richards, et al., 1954) and an average value of (1195 + 353)/2=774 pounds of nitrate per acre on native sod, and subtracts this value from those obtained at H3 and H7 and then removed 238 pounds of fertilizer nitrate one is left with an excess of 6243 pounds of nitrate per acre for H3 and 912 pounds of nitrate per acre for H7. There is 4 times as much nitrate at H7 as could be produced by fertilizer if all fertilizer were converted to nitrate and leached and 26 times as much at H3. Therefore, fertilizer cannot be the sole or major source of nitrate at the Brickley-Hoagland site.

Cultivation of native sod has been shown to facilitate conversion of organic material to nitrate at a rate higher than the plants can use it. The excess nitrate is leached below the root zone (Kreitler, et al., 1975; Reinhorn, et al., 1974; Swaby, et al., 1963). Although there is some disagreement, researchers generally feel that a new nitrogen cycle equilibrium is reached in a relatively short time (2-10 years). When equilibrium is established, the amount of nitrate produced by microorganisms from dead organic material is used by the crop, the crop residue provides dead organic material to the microorganisms, and nitrate leaching below the root zone approaches zero (Jenkinson, 1963; Reinhorn, et al., 1974; Kreitler, et al., 1975). The level of organic nitrogen below cultivated land should be less than that below native sod.

Several indirect lines of evidence indicate that the bulk of the nitrate in the profile is derived from nitrogen cycle disequilibration caused by cultivation. 1) The water on native sod carries no nitrate, the water on cultivated land carries up

Table 9. Amount of nitrate in the profile from holes at the Brickley-Hoagland site

Pounds per ounce of nitrate in the profile for three densities at four holes

Hole	1.5 g/cc	1.4 g/cc	1.3 g/cc
B5	1379	1287	1195
B8	407	380	353
H3	8372	7814	7255
H7	2220	2072	1924

to 172 ppm nitrate. 2) There is much more nitrate in the profile than can be produced by leaching all the fertilizer ever applied as nitrate. 3) Although native sod does carry some nitrate in the profile, there is more below the cultivated land than the sum of native sod nitrate and all fertilizer nitrate. 4) Bedrock ammonium does not appear to be depressed below cultivated land relative to the sod. 5) Nitrate levels fall off in bedrock. A further test of the hypothesis that cultivation of sod produced the nitrate would be to compare the organic nitrogen levels in the soil on native sod and cultivated land. The organic nitrogen should be lower under the cultivated land than under the sod. Samples of sufficient detail from the soil are not available but will be collected and analyzed soon.

Although intuition might suggest that most of the nitrate produced as a result of cultivation should be leached from the system in the last 67 years, the large amounts of nitrate in the profile suggest that this is not the case. The extremely high nitrate values at the top of H3 might be explained if one assumes that there is very little vertical leaching on the fence row but that the aeration and moisture regimes have changed so that organic matter is being converted to nitrate. If the above assumption is correct, then the amount of nitrate in H3 minus 774 pounds of nitrate per acre present naturally approximates that nitrate produced by cultivation (6481 pounds of nitrate per acre). The difference between the level of nitrate at H3 and that at H7 approximates the amount of nitrate leached in 67 years (5331 pounds per acre). Finally, if one divides the amount of nitrate leached by the number of years of cultivation, the rate of leaching is obtained (7255-1924)/67=80 pounds per acre per year). It may be that significant leaching and removal of nitrate did not begin until the practice of summer fallow began to contribute large amounts of water to the ground water table. If this is the case, one should divide by 51 years not 67 years, since summer fallow was first used about 1923. The rate of leaching then becomes 104 pounds per acre per year. At the former rate, it should take approximately 1924/104=18 years to finish leaching the Hoagland site.

Several assumptions have been made in arriving at these rates which the reader should recognize. 1) A soil density of 1.3 was assumed. 2) The sole nitrate source is conversion of organic material to nitrate by cultivation of sod plus the nitrate present before cultivation. 3) H3 represents the total amount of nitrate originally produced by cultivation plus that present naturally at the beginning of cultivation. 4) H7 represents the total amount of nitrate left. 5) The rate of leaching has been constant and linear. 6) No nitrate is presently added to the sub-root system at H3 or H7. The nitrogen cycle is near equilibrium at the surface at both holes.

Considerable care should be used in extrapolation and use of the rate results. Profiles of different permeability and physical characteristics probably have somewhat different rates. The length of time needed to leach the profile is probably a minimum time.

The rate may fall off exponentially as the amount of nitrate drops. The rate may also vary depending on how fast the water table rises, and whether or not new nitrate is being added to the system below the root zone. If new nitrate is being added, then the rate of leaching is faster, and the rate of profile nitrate depletion may be +, -, or 0 depending on the relative rates of addition and removal. The rate of removal of other ions is not known and may not be the same as the rate of removal of nitrate. The rates for other ions must be recalculated to account for their different atomic weights and the different loads of the different ions if the nitrate rate is extrapolated. The nitrate rate can be tested by calculating the difference between the organic nitrogen values on the sod and cultivated land, converting the difference to nitrate in pounds per acre, and determining how this difference compares to the amount of nitrate present in the entire profile at H3, H7, B8 and B5. This work will be done.

2. Other sites

Some rock and water samples were analyzed from sites other than the Brickley-Hoagland pair in the process of preparing procedures. Some of the results are important.

a) Location

The Bokma site is located west of Conrad and has the well designation B0. Site data compiled jointly with Marvin Miller and submitted by him as part of the interim report are included below.

Site 10. Conrad region - Bokma
County: Pondera
Location: T. 28 N., R. 3 W., sec. 16 (several miles west of Conrad)
Research Team: Miller, Custer and Bergantino
Owner: Ron Bokma
No. of Holes Drilled: 23 (all cased, flushed, and gravel packed)
No. of Holes Drilled Previously: 2 (ARS rig-Sidney)
No. of Holes Sampled from Auger: 5
No. of Holes Cored: 2
Other Data: Water levels taken
Topography: Moderately sloping glacial moraine adjacent to the Benton Bench)
Surficial Material: Glacial drift (two tills and some meltwater deposits)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Alternate crop-fallow throughout area, some native sod along bench margin to the west
Remarks: Seeps are numerous around the margins of the Benton Bench. The bench, which is extensively farmed, is capped by Eagle Sandstone. Significant amounts of water seem to be migrating downslope and creating saline conditions. Two shallow holes were drilled earlier in the year by ARS (Halverson).

BO$_{spring}$ is a spring near the Bokma farm directly above the Bokma site coming out of the Eagle sandstone. BO 19 is in a pasture above the Bokma site but below the spring. BO 4 is just above the seep. BO 23 is in the seep and BO 22 is below the seep in the area where the bedrock drops below the reach of the drilling equipment. Since the top of the bench above the Bokma site is in sod, and since there are springs in the face of the Eagle sandstone escarpment, much of the water discharging into the seep probably comes from the slope in front of the bench. Nitrogen analyses of the rock material are not possible because of preservation problems, but water analyses for nitrogen were performed.

The Anderson site and Gettle-Jones site are located near Conrad and have the well designations LA and GJ respectively. Site data compiled jointly with Marvin Miller and submitted by him as part of the interim report are included below. LA 2 is a discharge well, LA 8 is a recharge well. GJ 2 is a discharge well, GJ 5 is a recharge well.

Site 9. Conrad region - Anderson area
County: Pondera
Location: T. 28 N., R. 2 W., sec. 27 (east of Conrad)
Research Team: Miller, Custer and Brown
Owner: Leroy Anderson
No. of Holes Drilled: 14 (all cased, flushed, and gravel packed)
No. of Holes Drilled Previously: 2 (ARS rig-Sidney)
No. of Holes Sampled from Auger: 4
No. Holes Cored: 0
Other Data: Water levels taken
Topography: Gently undulating glacial ground moraine
Surficial Material: Glacial drift (two tills and scattered gravel lenses)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Alternate crop-fallow farming system; single-row windbreak trends N-S through the middle of the area
Remarks: The ARS (Halverson and Brown) briefly examined the area earlier in the summer and drilled two shallow test holes in the area. Discontinuous gravel lenses associated with several small upland potholes seem to be contributing water to the seep.

Site 11. Conrad region - Gettel, Jones area
County: Cascade
Location: T. 22 N., R. 2 E., sec. 6,7 (southeast of Power)
Research Team: Miller, Custer and Bergantino
Owners: Arnold Gettel and Howard Jones
No. of Holes Drilled: 9 (all cased, flushed, and gravel packed)
No. of Holes Sampled from Auger: 4
No. of Holes Cored: 0
Other Data: Water levels taken
Topography: Gently sloping ground moraine upslope from internally drained basin (Benton Lake)
Surficial Material: Glacial drift (two tills)
Bedrock Type: Colorado Shale (Cretaceous)
Vegetation: Alternate crop-fallow farming
Remarks: This is a large seep area and possibly could be used for Krall's cropping investigations. If it is used, possibly more holes will be required. The Colorado Shale contains discontinuous hard siltstone lenses in this area. Sommerfelt, several miles south, is draining seep water into one of the siltstone lenses and into nearby coulee, which drains down through research area.

The Flesch site (LF) is located near Shelby. The Skari site (SK) is located near Chester. Site data are included below. LF 5 is in a pasture above LF 3 which is in a discharge area. SK 2 is in an area where the bedrock is near the surface and may be located in a recharge area. SK 4 is in the broad valley bottom and is not seeped. SK 4 did not penetrate bedrock.

Site 12. Shelby region - Flesch area
County: Toole
Location: T. 33 N., R. 2 W., sec. 4, 5, 8, 9
Research Team: Miller, Custer and Bergantino
Owner: Lester Flesch
No. of Holes Drilled: 10 (all cased, flushed and gravel packed)
No. of Holes Sampled from Auger: 3
No. of Holes Cored: 1
Other Data: Water levels taken, resistivity profiles run, water samples collected
Topography: Gently sloping ground moraine dissected by small drainageway
Surficial Material: Glacial drift (two tills)
Bedrock Formation: Colorado Shale (Cretaceous)
Vegetation: Native sod; alternate crop-fallow farming in headwaters area
Remarks: The area is native sod surrounded by farmland. Recharge potholes are numerous in upper areas. Water seeping into the coulee above the reservoir is believed to have killed four cows.

Site 13. Shelby region - Skari area
County: Liberty
Location: T. 34 N., R. 5 E., sec. 25, 26, 35, 36 (north of Chester)
Research Team: Miller, Custer and Bergantino
Owner: Skari Brothers
No. of Holes Drilled: 11 (all cased, flushed, and gravel packed)
No. of Holes Sampled from Auger: 4
No. of Holes Cored: 0
Topography: Ground moraine sloping toward glacial sluiceway and possibly temporary lake
Surficial Material: Glacial drift (two tills: sand and gravel along sluiceway)
Bedrock Formation: Claggett Shale (Cretaceous)
Vegetation: Grass area and crop-fallow farming
Remarks: The area is large and undoubtedly will require more and deeper holes. Bedrock was encountered in only one hole. The sluiceway seems to be an important source of water, but large surrounding recharge area also contributes.

The Newby site is located near Glasgow. The wells at this site have the prefix RN. RN 6 is above the seeps, RN 9 is in a seep near Tomato Can Creek. RN 1 is in a seep above RN 9. No detailed nitrate analyses are planned because no paired sod holes are available. Frozen samples have been preserved.

Site data is included below.

Site 15. Glasgow region - Newby area
County: Valley
Location: T. 30 N., R. 42 E., sec. 14 (northeast of Glasgow)
Research Team: Custer, Bergantino and Sonderegger
Owner: Ruth Newby
No. of Holes Drilled: 13 (all cased, flushed and gravel packed)
No. of Holes Sampled from Auger: 6
No. of Holes Cored: 0
Topography: Ground moraine sloping toward drainageway
Surficial Material: Glacial drift (outwash over till)
Bedrock Formation: Bearpaw Shale (cretaceous)
Vegetation: Alternate crop-fallow farmland
Remarks: Water seems to be carried in the weathered zone (3 to 5 feet) of the Bearpaw Shale.

b) Water analyses

Water was sampled at 4 holes at the Bokma site and analyses were made for ammonium, nitrate plus nitrite, bicarbonate, pH, and specific conductance (Table 10). Although the spring was sampled after it flowed on the ground in a cattle pasture, the nitrate levels are very low and very close to the values from the ground water in BO 19 in the nearby pasture. The water from BO spring is therefore judged to be uncontaminated. Both the spring water and the pasture ground water also have moderately low specific conductances (about 3000 micromhos/cm), and serve as a base line against which the holes on the cultivated land and in the seep can be compared.

BO 23 is anomalous. If one disregards the data from BO 23, there is a nearly linear increase in bicarbonate and specific conductance with distance from BO 19. BO 23 is in the seep, the water is close to the surface and the 4 inch casing was not covered. The consistently low values may indicate dilution by runoff and rain water. Thus, the water analyses indicate a con-

Table 10. Water analyses for Newby, Bokma, Anderson and Gettel sites. The holes are listed moving progressively away from the recharge area.

	NH_4	NO_3	HCO_3	pH	Sp Cond	Temp °C
May 25, 1975, Bokma, Anderson, Gettel sites (Conrad area)						
BO spring	1.3	2.5	402	8.28	2777	-
BO 19	3.3	1.8	358	7.38	3393	9
BO 4	0.5	89.5	639	7.10	12350	8
BO 23	1.7	37.6	438	7.51	3422	8
BO 22	0.0	43.4	947	7.37	25296	9
LA 8	1.3	73.9	331	7.70	17886	6°
LA 2	1.4	64.2	444	7.60	19926	6°
GJ 2	1.5	3.2	246	6.58	6725	8
Gj 5	1.3	23.7	0	4.57	4921	3
June 13, 1975, Newby site						
RN 6	0	0	283	7.40		
RN 9	0	43.4	275	7.00		

tinued increase in ground water salinity even east of and below the seep.

The pH and nitrate values do not fit this pattern. The pH of 8.3 at the spring may reflect near equilibration with calcite in the soil profile. The pH of the water in the wells is around 7.3. This discrepancy may be due to the fact that there is a vertical fracture system in the till which conducts the water along calcite free(?) channels. Moving from the pasture across the seep, the nitrate level climbs to 90 and then drops to 40. The cause of the drop in the level of nitrate is not known. One explanation may be that the saturated seep is reducing the nitrate to a gas which is then lost.

Relative elevation data is not available and is needed at the Bokma site before more can be said about the cause of the seep location. One speculation is that the seep occurs because there is a flattening in the gradient of the perching Colorado shale followed by another steeper gradient so that water collects briefly at the flat spot and then moves on. This scheme would explain the linear increase in total dissolved solids across and beyond the seep.

At the Anderson site, there is little difference between the suspected recharge and discharge areas. The water is high in nitrates and specific conductance. LA 8 may not be a recharge well.

At the Gettle-Jones site, the nitrate values are low, and the specific conductance increases from the recharge to the discharge area. The pH of the water in this area is acid. An acid pH also occurs at the nearby Sommerfelt farm and appears to be a general local condition in this area (Miller, personal communication).

At the Newby site the nitrate is zero in the recharge area and 43 ppm in the seep. The low nitrate values in the recharge area may be related to the sandy lenses at RN 6. These lenses may provide for rapid nitrate leaching. In the seep these lenses are absent and leaching is probably slower.

c) Rock analysis for ammonium and nitrate

Ammonium and nitrate were extracted from several samples from the bottoms of holes to test for the presence of ammonium. Some shallower samples were also run during the development of the experimental technique. Table 11 presents the data. The data in Table 11b should be used with some skepticism since analytical techniques were being developed when the data was collected.

At the Newby site, the bottom of RN 1 showed considerable ammonium. The trend between 40 and 50 feet indicates that no ammonium exists above about 35 feet. The nitrate levels at depth are low.

A comparison of the data from the Flesch and Skari sites is important. At the Flesch site the discharge water has nitrate levels as high as 1000 ppm (Miller, personal communication, 1975), and cattle have been killed (Lester Flesch, personal communication, 1974). This high nitrate is reflected as 219 ppm of nitrate in the upper 5 feet of the discharge profile. The ammonium is present relatively near the surface. At the Skari site, the till at 13 feet has even more nitrate than at the Flesch site. This is alarming because Mr. Skari is planning to develop stock water from the ground. Nitrate levels in the till above the shale indicate that the water may be poisonous.

The ammonium levels at the Skari site are also very high in the Claggett shale (SK 2). SK 2 penetrated shale because of a bedrock high which placed the shale within reach of the drill. In general, drilling at the Skari site did not reach shale because the till is extremely deep. SK 4 never reached shale. Ammonium and nitrate values in the deeper portions of SK 4 are much lower than in the Claggett shale and overlying till at SK 2 and are of the same order of magnitude as near Rapelje. Although SK 2 may be anomalous, detailed nitrate testing of well water should be made before ground water is developed for stock or domestic use.

Further nitrogen studies of the rock material are probably not warranted at Skari site because of the size of the valley bottom, the extreme depth to bedrock (greater than 60 feet), and the large size of the hydrologic system. The Flesch site would need more detailed sampling from the cultivated recharge area if further study were to be made of the nitrate problem.

On the basis of the few samples analysed, very high nitrate values (greater and 170 ppm) in the upper profile are associated with small (20-25 feet) depths to bedrock. To demonstrate whether this nitrate comes from the bedrock, ammonium, or natural bedrock nitrate spots, or cultivation or fertilization in these

Table 11a. Nitrate and ammonium analyses for some selected rock samples

Hole	Depth	% Moisture	NH_4(ppm)	NO_3 (ppm)
RN1	38-42	44.88	6.19	12.03
RN1	48-52	43.36	27.8	-
SK4	53-55	17.41	23.80	3.10
SK4	57-59	17.94	14.43	-
SK2	13.5	-	6.3	269.50
SK2	45-48	35.83	146.5	91.50
SK2	48-50	-	136.1	51.80
KH5	55-58	18.48	16.1	-

Table 11b. Nitrate and annomium analyses for selected rock samples performed during the development of analytical technique

Hole	Depth	% Moisture	NH_4 (ppm)	NO_3 (ppm)
SK2	28	20.42	5.54	19.58
B6	1-3	12.82	-	-
B6	28-33	7.14	4.5	-
LF3	2-5	21.32	-	219.48
LF3	23-28	21.05	15.72	38.71

areas would require more holes on carefully paired sites.

3. Discussion of the nitrate problem

On the basis of the data from the Rapelje area, the source of the nitrate is tentatively assigned to cultivation of native sod. Extreme care should be exercised when using water in areas that have been broken up. If large tracts are to be cultivated for the first time, methods should be developed to reduce the rate and amount of nitrate production. Careful attention to cultivation techniques might allow for nitrate production at a rate which could be used by plants. Timing of cultivation to reduce nitrate loss might also be important.

The possible dangers of nitrate production by cultivation should be monitored in detail in areas where scalping and furrowing are being applied to native sod to improve over-grazed range (for example the Rohde site). One of the after effects of these practices may be nitrate production. Furthermore, if the sod is allowed to reestablish itself and is then rescalped, multiple nitrate surges might be produced. If the gravel beds at the Rohde site have much permeability, the nitrate may move into the water system rapidly.

In areas where water is collected for stock use and nitrates are known to be present, farmers should be aware that evaporative or freeze concentration of the liquid can raise the nitrate concentration to a poisonous level. In high nitrate areas, continual monitoring of the nitrate levels and/or salinity would be desirable. A simple inexpensive semiquantitative nitrate test is badly needed.

"...Alfalfa has the apparent capacity to remove nitrate from the profile to at least a depth of 20 feet in alluvial soils" (Vietz, et al., 1971, p. 23). Wise use of alfalfa in cropping rotations may help reduce ~~produce~~ nitrate levels as well as water levels. If the alfalfa is plowed under in the cropping rotation, however, a study should be made to be certain that the decay of organic nitrogen in the deep root system of the legume does not produce a nitrate problem of equal or greater magnitude than before alfalfa introduction.

If humans (especially infants) are drinking high nitrate water, the findings of Gruener and Shuval (1970) summarized by Vietz, et al., (1971) should be considered. They found that Vitamin C aids in the prevention or cure of methemoglobinemia.

2. Sodium, Potassium, Calcium, Magnesium, Chloride, Sulfate, Bicarbonate, Carbonate, Specific Conductance

   a. Analytic methods

      1) Na, K -- Atomic absorption or flame emission

         a. flame: air propane reduces ionization problems.

      2) Ca, Mg -- Atomic absorption

         a. flame: Nitrous oxide - acetelene using 300 ppm potassium as an ionization supressant. Avoids the use of a releasing agent.

      3) SO_4 -- Thorin method (Brown, et al., 1970)

      4) Cl -- Mercuric Nitrate method (Taras, 1971).

      5) HCO_3, CO_3 -- Acid titration (Brown, et al., 1970)

      6) Specific conductance -- Sproul conductivity cell with a cell constant of 1 corrected to 20°C using Richards, et al. (1954).

   b. Extraction procedure

Extraction of the total ionic load (salt load) is needed to find out how much salt needs to be removed to remove the salinity problem. The distribution of the total ionic load with depth will also provide information about the ion sources, leaching processes, and their rates.

The extraction procedure for total ionic load is difficult. The saturation extract (Richards, et al., 1954) will not work because the ionic loads exceed that soluble in the amount of water used in a saturation extract. Furthermore, gypsum and calcite are present in the profiles. These minerals are slightly soluble and force the use of large amounts of water. In samples tested, 750 ml of water were progressively flushed through 10 grams of rock material and sulfate was still being leached on the last wash. Large amounts of water of the order of 1000-4000 ml will be needed. If all the salts are removed, then the salt load determination will include gypsum and calcium carbonate. The inclusion of these minerals is not necessarily desirable. Calcite is precipitated, not dissolved, in the Cca horizon of soils throughout eastern Montana. Neither gypsum nor calcite are highly soluble salts. Neither gypsum nor calcite are deletarious to soil structure. However, if small volume extracts which do not dissolve all the gypsum and calcite are used, these minerals will contribute ions to the extract to an unknown extent.

The best way around the calcite-gypsum problem appears to be a 2N potassium acetate leaching system buffered with triethanolamine to a pH greater than 8.4. The high pH prevents solution of calcite. The 2N KoAc provides an exchange ion with a minimum common ion effect. The gypsum load can be evaluated by taking the total calcium load, subtracting exchangeable Ca, and calling the remainder gypsum.

There may be some objection to using a high ionic strength alkaline leach, since the water entering the natural system is dilute and neutral. A distilled water leach using large volumes, however, is also not very close to the natural system. The 2N KoAc leach has several positive attributes. The high ionic strength causes the clays to flocculate leading to a clean extract and retention of the small particles which are very reactive due to their high surface area. The high concentration of potassium ions also replaces all the ions on the exchange sites so that variable removal is avoided. The potassium ion was chosen because of its moderately high affinity for the exchange sites and its relatively low concentrations in the seep waters. A neutral pH would leave a question as to how much Ca from calcite was introduced into the leach. A pH of 8.4 prevents this problem.

The problems of determining exchangeable cations are discussed in Richards, et al. (1954, p. 19-20). Calcium and magnesium cannot be determined accurately in soils that contain gypsum and calcite. The closest approximation is to take a saturation extract with distilled water at a pH of 8.4 and then take an extract on another subsample using an identical amount of liquid but substituting KoAc at a pH of 8.4. The difference in the analyses should be exchangeable cations. There are several invalid assumptions used in this procedure. 1) The chemistry of the two extracts is the same. There are no common ion or ionic strength effects. 2) Only potassium will go on the exchange sites, not other ions in the solution. 3) The amount of calcite and gypsum dissolving in both the water and the potassium acetate solution is identical. 4) The chemistry of the extracts applies to the chemistry of the water in the profile at other moisture contents. These invalid assumptions make it clear that there is no way to get an accurate estimation of the exchangeable cations. The procedure mentioned above appears to be the best available, and would provide an estimate of the exchangeable calcium which could be subtracted from the total calcium to increase the accuracy of the gypsum estimate.

The use of a saturation extract in the extraction procedure requires two large samples. The drilling samples are often too small. The first step in the extraction procedure will be to compare the total ionic load with the cation exchange capacity. If more detailed exchangeable ion data are indicated by these results, the exchangeable ion procedure will be refined and performed.

D. Mineralogical Analyses

Forty-seven x-ray diffraction analyses were completed on seep related salts and clays. The following phases were identified.

1. Calcite -- $CaCO_3$
2. Gypsum -- $CaSO_4 \cdot SH_2O$
3. Thenardite -- Na_2SO_4
4. Loweite -- $Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$
5. Jarosite -- $KFe_3(SO_4)_2(OH)_6$
6. Smectite -- A clay mineral
7. Illite -- A clay mineral
8. Kaolinite -- A clay mineral

a. One problem encountered with the identification of the salts is the high hydration states which are easily achieved. Drying and quick analysis is usually needed to identify the salt mineralogy. The minerals identified in the lab may occur in nature with different hydration states. Thus, thenardite identified in the dry sample may occur as mirabilite ($Na_2SO_4 \cdot 10H_2O$) in

For present purposes, the changes in hydration state have been recognized, but the fundamental difference between Na_2SO_4 and Na_2SO_4 XH_2O is considered unimportant.

E. Seismic refraction work was done at 12 locations in Rapelje, Denton, and Coffee Creek using a Bison seismograph and hammer. The work was done to determine the feasibility of using this technique to determine depth to bedrock and depth to water table. The power of seismic refraction is that the seismic velocities can be used to infer the type of material that exists at a specific depth (for example sand or sand with water, till or till with water, or shale).

Marvin Miller of the Montana Bureau of Mines and Geology used resistivity techniques, and drill holes were completed at the same locations. The seismic method looks discouraging at this time since there did not appear to be a high degree of correlation between the drill holes, resistivity and seismic interpretations.

The poor correlation may be due to the response of the seismic waves to the capillary fringe. Slight changes in the physical properties of the unit in response to the capillary fringe probably explain some of the problem.

F. Literature search was continued and a bibliography was begun on computer. The bibliography can be sorted on several fields and accessed (Famulus format). About 357 references were placed on the file. Due to the lack of secretarial staff, and the large amount of time needed to type references, activity in this area will be limited in the future. A copy of the bibliography is enclosed.

G. Extensive investigation of saline seep in Montana.

Several overlay maps were created in the search for criteria to predict where saline seep can be expected. The data collected on the location of saline seep in Montana by the County Committees for Rural Development for State Lands was transferred at 1:500,000 and overlayed on the Geologic map of Montana (Ross, et al., 1955). No attempt was made to smooth out inconsistencies in seep location data. The map is a working map, and is unwieldy for general use. Information on land use is so inaccurate, that a scale of 1:2,000,000 was chosen to do further overlays. These overlays fit the scale of the generalized saline seep maps distributed by the Montana Department of State Lands, and the geologic map in Montana Bureau of Mines and Geology Bulletin 26 (Perry, 1962). The land use map from the National atlas (U.S. Geological Survey, 1970) and a map of areas cultivated but reported as not affected by saline seep are presented in Plates 1 and 2. To reduce the need for folded maps, small copies at a scale of 1:4,300,000 are presented for saline seep, geology, land use, precipitation, and areas of cultivation with no seep (Figures 6-10). Some scale distortion during reproduction makes these maps less accurate than those at 1:2,000,000, but the general trends can be seen. Copies of the larger scale maps are included for technical use.

A list of bedrock formations over which seep occurs was made (independent of glacial till). This list is presented in Table 12A along with a list of units recognized on the geologic map Table 12B. The formations with no stars in Table 12B have no seep reported over them. Although glacial drift might control the salinity rather than the bedrock, no unit so restricted was found. No unit younger than Paleozoic which has cultivated farming over it is without seep except for hard non-pyroclastic igneous rocks. The rocks older than Mesozoic tend to outcrop in the mountains and are not generally farmed. At this time there does not appear to be a lithologic control for the occurrence of saline seep. This lack of correlation was somewhat surprising for river deposited Flaxville gravel and Quaternary alluvium. More detailed analyses of the relationships between seep and geology will be made in these apparently anomalous areas.

Precipitation was also examined in terms of saline seep (Figure 9). No pattern is evident either on this map or on a more detailed preliminary map of precipitation compiled by the SCS, but not released for publication. High precipitation areas occur in the mountains where there is no farming. Seeps occur in low precipitation areas, 12-20 inches of rain.

Since saline seep is induced by dryland and irrigated farming (Bahls, et al., 1973), a map of land use versus seep location should show where saline seep might be expected but has not occurred. This information is important because it helps identify factors which are critical to seep formation. Detailed land use information is very difficult to find. One source is from Montana Water Resources Board (1968) (Figure A); one is enlarged from the National Atlas (U.S. Geological Survey, 1970) (Figure 8B). The differences between the two maps are striking. Clearly there are gross generalizations on both. An attempt was made to obtain a larger copy of the more recent and more detailed map through the Agricultural Research Service. No response has been received. A future source of more detailed land use maps may be the River Basin Maps now being compiled by the SCS but not yet finished. To compile an accurate land use map of the entire state is beyond the scope of this study. Because of the apparently greater detail of the land use map from the National Atlas, this map was blown up to a scale of 1:2,000,000 (Plate 1, or Figure 10).

Figure 6. Saline seep in Montana. Source: Montana Department of State Lands map of saline seep in Montana, 1974.

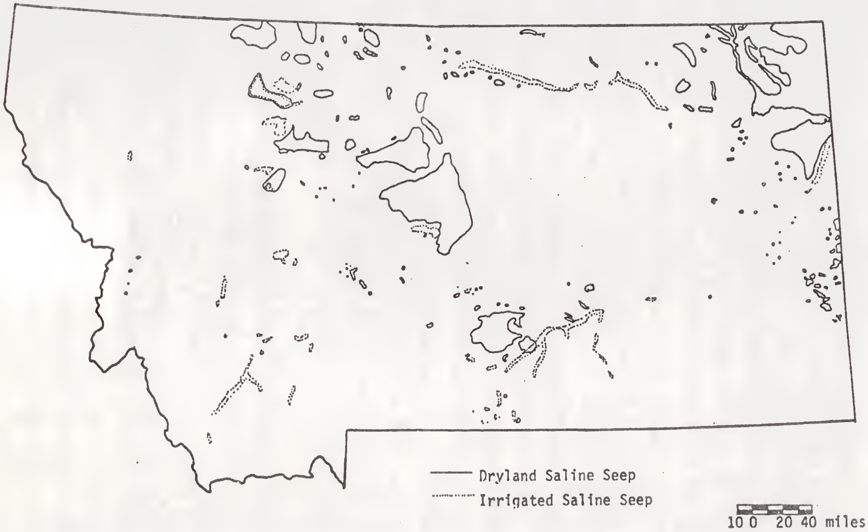
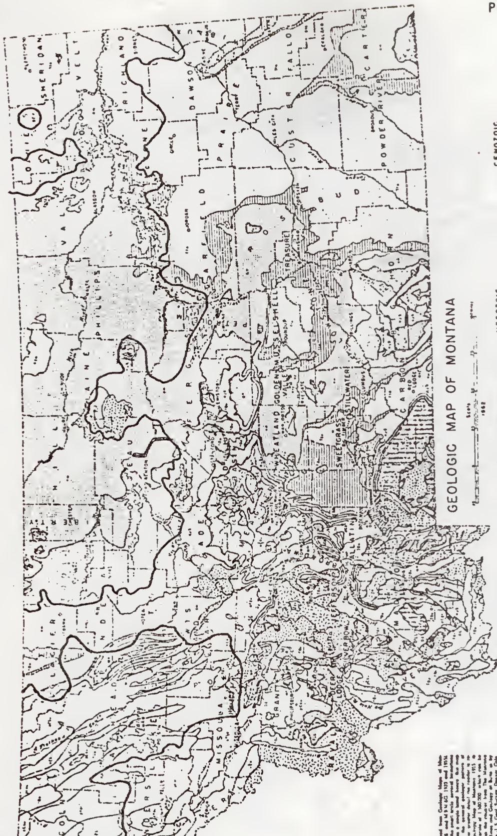


Figure 7. Generalized Geology of Montana, Perry, 1962.


GEOLOGIC MAP OF MONTANA
1962
EXPLANATION
SEDIMENTARY ROCKS
CENOZOIC
TQu, Tertiary sediments, Willow Cr fm, glacial deposits, and alluvium in western Montana
Tfw, Fort Union, Flaxville, Wasatch, and White River fms in central and eastern Montana
TKl, Livingston fm of Crazy Mts area, includes Montana group above Eagle ss, Hell Cr, and Fort Union fms
MESOZOIC
Ksm, St Mary River formation of north-central Montana
Khc, Hell Cr fm, central and eastern Montana
Km, Montana group: Telegraph Creek, Eagle, Claggett, Judith River, and Bearpaw fms over most of state, Fox Hills ss and Pierre sh in extreme east
Kc, Colorado group: Thermopolis, Mowry, Belle Fourche, Greenhorn, Carlile, and Niobrara formations in south-central and eastern Montana, and the Blackleaf fm and Marias River shale of north-central Montana
KJTR, Lower Mesozoic Ellis group, Morrison formation, and Kootenai fm includes Triassic Dinwoody where present
PALEOZOIC
MP, Mississippian, Pennsylvanian, and Permian fms: Madison group, Big Snowy group, Amsden, Quadrant Tensleep, and Phosphoria formations
DC, Devonian and Cambrian formations Flathead, Wolsey, Meagher, Park, Pilgrim, Red Lion, Maywood, Grove Cr, Jefferson, and Three Forks formations
PRECAMBRIAN
pCb, Belt formations undifferentiated
pCbu, Upper Belt formations of the Piegan and [illegible] groups
pCbl, Lower Belt formations of the Ravalli group and the Prichard formation
pCgs, Pre-Belt gneisses, schists, marbles, and associated rocks of the Cherry Creek series, pre-Cherry Cr fms, and the Stillwater igneous complex
IGNEOUS ROCKS
TKv, Volcanic Rocks
TKi, Intrusive Rocks

—— Maximum extent of glacial ice (Flint, 1971, Lemke, et al, 1965).

Source: Perry,1962.

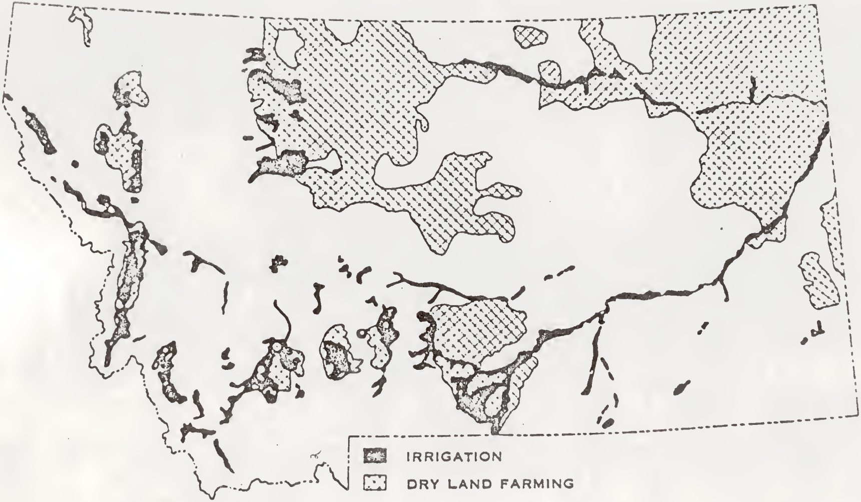
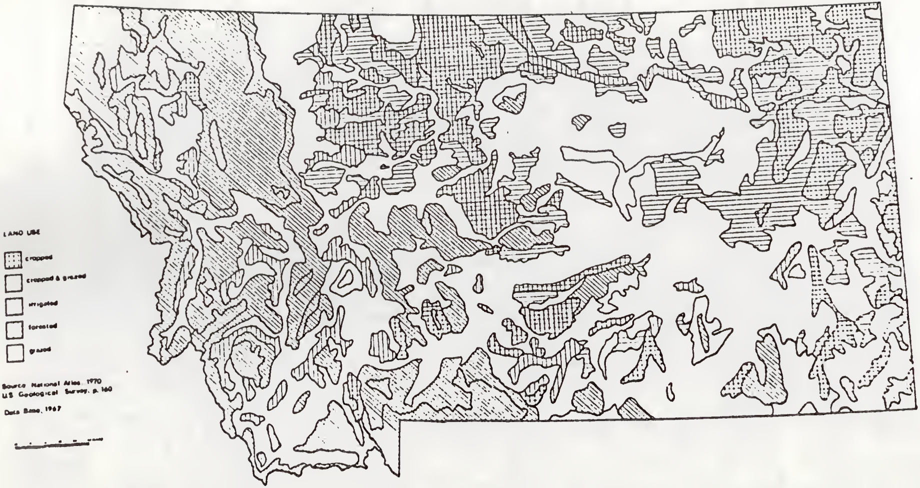


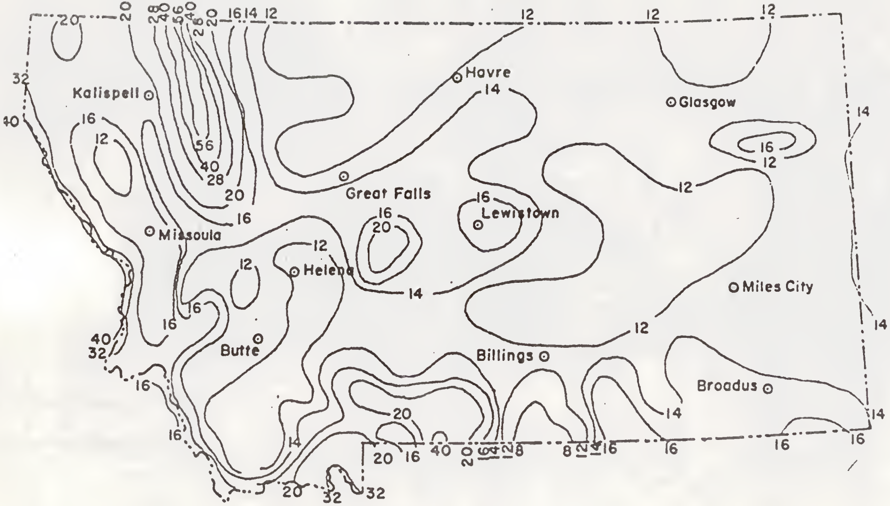
Figure 8a. Land use in Montana, Montana Water Resources Board, 1968.



Source National Atlas, 1970
U.S. Geological Survey, p. 160

Data Base, 1967

Figure 8b. Land use in Montana, U.S. Geological Survey, 1970.



MONTANA
MEAN ANNUAL PRECIPITATION
(IN INCHES)

Figure 9. Mean annual Precipitation, Montana Water Resources Board, 1968.

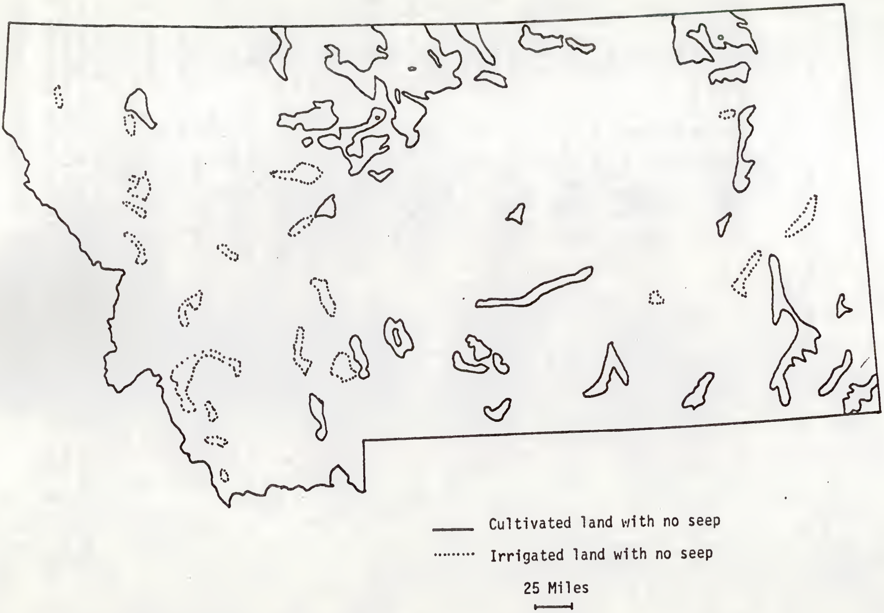


Figure 10. Map of cultivated land in Montana with no saline seep.

Table 12a. Units which have saline seep by county

1. Sheridan -- Tfu, Qal, Tf
2. Daniels -- Tfu, Tf, Qal, Khc
3. Valley -- Tf, Kb, Kfh, Khc, Kjr, Kcl, Qal
4. McCone -- Qal, Tfu, Kfh
5. Garfield -- No seep reported
6. Richland -- Tfu, Qal
7. Dawson -- Tf, Qal, Tfu
8. Prairie -- Tfu, Qal
9. Wibaux -- Tfu
10. Fallon -- Tfu, Khc, Kp, Kfh, Qal
11. Custer -- Tfu
12. Carter -- No seep reported
13. Powder River -- No seep reported
14. Rosebud -- Qal, Khc
15. Bighorn -- Qal, Kcb, Kmo, Tfu, Kf
16. Treasure -- Qal
17. Yellowstone -- Keu, Kcl, Kjr, Kl, Khc, Tfu, Qal
18. Golden Valley -- Kb, Kc, Khc, Kjr
19. Musselshell -- Tfu, Qal
20. Petroleum -- No seep reported
21. Fergus -- QTt, Kk, Ju, Mu, Pu, Kc, Kcl, Tg, Kb, Keu
22. Blaine -- Kjr, Kb, Qal, Kfh
23. Phillips -- Qal, Kcl, Kjr, Kb
24. Liberty -- Keu, Kjr, Kcl
25. Hill -- Kcl, Kjr, Kb, Kc
26. Choteau -- Kvi, Keu, Kc, Kcl, Kjr, Qal
27. Cascade -- Kk, Kc
28. Judith Basin -- QTt, Kc, Ju, Kk
29. Meagher -- Qal, Ts, Keu, Cu, Du
30. Wheatland -- Kjr, Keu, QTt, Kb, Keu, Kc
31. Sweetgrass -- Tfu
32. Park -- no location data
33. Toole -- Kc, Kvi, Ktc, Kcl
34. Glacier -- Kc, Ksm, Kh, Kb, Qg, Twc
35. Pondera -- Ktm, QTt, Kvi, Ktc, Ts, Kc
36. Teton -- QTt, Kvi, Kcl, Ts, Kc, Ktc, QTt
37. Lewis and Clark -- Ktm, Qg, QTt, Qal, Pg, Qal, PCs
38. Broadwater -- No seep reported
39. Powell -- Qal, Kc, Ts
40. Deer Lodge -- Qal
41. Jefferson -- Qal
42. Madison -- Kk, Ts, Qal
43. Gallatin -- Qal, Ts
44. Beaverhead -- Qal
45. Ravalli -- Qal
46. Lake -- Qal

All western counties not listed have no seep reported.

Table 12b. List of Units on the Geologic Map of Montana, Ross, et al., 1955, which have saline seep over them. The numbers refer to counties in table 12a.

Qal -- Alluvium -- 1, 2, 3, 4, 6, 7, 8, 10, 14, 15, 16, 17, 19, 22, 23, 26, 29, 37, 39, 40, 41, 42, 43, 44, 45, 46
*Qgl -- Glacial lake deposits
Qg -- Glacial Drift (Not continental glaciation) -- 34, 37
Tf -- Flaxville Gravel -- 1, 2, 3, 7
*Ta -- Arikaree formation -- not farmed?
*Twr -- White River formation -- not farmed?
*Tw -- Wasatch formation -- not farmed?
Tfu -- Fort Union formation -- 1, 2, 4, 6, 7, 8, 9, 10, 11, 15, 17, 19, 31
Twc -- Willow Creek formation -- 3, 4
QTt -- Terrace deposits -- 21, 28, 30, 35, 36, 37
Ts -- Tertiary sedimentary rocks -- 36, 39, 42, 29, 35, 43
*Tv -- Tertiary volcanic rocks
*Tg -- Tertiary coarse grained intrusives -- 21?
*Td -- Tertiary dikes and sills
Ksm -- St. Mary River formation -- 34
Kh -- Horsethief sandstone -- 34
Khc -- Hell Creek formation -- 2, 3, 10, 14, 17, 18
Kfh -- Fox Hills sandstone -- 3, 4, 10, 22
Kb -- Bearpaw shale -- 3, 18, 21, 22, 23, 25, 30, 34
Kjr -- Judith River formation -- 3, 17, 18, 22, 23, 25, 26, 30
Kcl -- Claggett formation -- 3, 17, 21, 23, 24, 25, 26, 33, 36
Keu, Kvi -- Eagle sandstone, Virgelle sandstone -- 17, 21, 24, 26, 29, 30, 33, 35, 36
Ktm -- Two medicine formation -- 35, 37
*Km -- Montana group -- formations in this group do have saline seep
*Kv -- Cretaceous volcanics
*TKb -- Boulder batholith
Kl -- Lennep sandstone -- 17
*TKl -- Livingston formation
Kdg -- Diorite and gabbro -- 10?
*Kp -- Pierre shale -- not farmed?
Ktc -- Telegraph Creek -- 33, 35, 36
*Kn -- Niobrara formation -- not farmed?
*Kcc - Carlile shale -- not farmed?
*Kg -- Greenhorn formation - not farmed?
*Kbf -- Belle Fourche shale -- not farmed?
Kcb -- Basal Cody shale -- 15
Kf -- Frontier formation -- 15
*Ku -- Cretaceous undifferentiated -- many Cretaceous units do have seep
Kc -- Colorado shale -- 18, 21, 25, 26, 28, 39, 30, 33, 34, 35, 36
Kmo -- Mowry shale -- 15
*Kt -- Thermopolis shale -- not farmed?
*Kib -- Border zone of the Idaho batholith
*Ki -- Idaho batholith
Kk -- Kootenai formation -- 21, 27, 28, 42

Table 12b. (continued)

No unit older than Cretaceous has unquestionable saline seep on it. Most of these older units are in the mountains and are not farmed. Most of the * units which are labeled not farmed? occur in the extreme southwest part of the state where land use maps indicate grazing land.

A map was made of locations where land is cultivated or irrigated and no seep reported (Plate 2 and Figure 10). Although the inaccuracies of location are great, and there are undoubtedly errors obvious to people who live in the outlined areas, there is some validity to the map. While working in the region between Conrad and Dutton, the author noticed a lack of saline seep along Interstate 15. The map outlines the area correctly (Plate 2, Figure 10). The next step in the extensive investigation should be to study some of the areas where saline seep is expected but does not occur, and compare these to seeped areas in a search for critical factors contributing to seep formation. The following areas are candidates for study.

1. Teton and Pondera Counties in the region that included the stretch of highway between Conrad and Dutton.
2. Liberty County along Highway 2.
3. Phillips County near T34N R30E.
4. Northeast of Circle in McCone County.
5. The Powder River drainage in Custer and Powder River Counties.
6. Along the Tonge River in Rosebud County.
7. Along the Bighorn River in Bighorn County.
8. Stillwater County northwest of Columbus.
9. Northwest of Grass Range in Fergus County.
10. Near Bozeman in Gallatin County.

A study of more limited areas will allow the use of parameters which are difficult to quantify for the whole state such as topography. Topography may still be a problem because detailed topographic maps are rare in dryland agricultural areas in eastern Montana. Perhaps air photos and topographic maps at a larger scale will do. These studies should probably be begun on areas not larger than a 7.5 minute quadrangle. In some cases, drill holes would be desirable, both for hydrologic and geologic information. Cores made by the highway department along primary highways may help.

The Montana Bureau of Mines and Geology is compiling a map of till thickness which will be of use in Teton, Pondera, Liberty and Phillips counties.

III. Summary of Conclusions

1. Ammonium extractions should be ran wet. Drying may reduce the ammonium level as much as 30%.
2. Potassium does not irreversibly lock ammonium in the samples studied.
3. Mercury chloride used as a preservative to prevent nitrogen changes caused by microorganisms leads to a 50% loss of nitrate plus nitrite upon Kjeldahl distillation with devarda's alloy.
4. No changes in the level of nitrate or ammonium were detected when solidified and untreated water samples were compared one week after sampling.
5. No significant difference in bicarbonate levels could be detected for samples analysed both in the field and the lab.
6. At the Brickley-Hoagland site,
    a. The native sod tends to be drier than the cultivated land. In general, the sod has 10% or less water and the cultivated land has 10% or more.
    b. The pH of a 1:1 slurry of rock material is about 1 pH unit more alkaline than the water sampled from the wells.

c. The ammonium in the well water is usually low. Presumably it is converted to nitrate.

d. There is no nitrate in the water below native sod. In the water below cultivated land, the nitrate is about 90 ppm in the winter and about 170 ppm in the spring. The recommended upper limit for drinking water is 45 ppm.

e. The bicarbonate level in the water below the sod and the cultivated land is similar.

f. The specific conductance of the water increases with increased distance from the recharge area both below the native sod and the cultivated area affected by saline seep.

g. In the rock material, ammonium was found at the bottom of the deeper holes. There did not appear to be a depression of the depth to ammonium below cultivated land. To establish this conclusion beyond doubt more paired sites would have to be drilled and holes a minimum of 60 feet deep would be required. The nitrate distribution indicates that these additional holes are probably not warranted at present.

h. In the rock material, there is more nitrate below the cultivated land than below the native sod.

i. The high levels of nitrate at the top of the hole and the low nitrate level at the bottom indicate a surface source for the nitrate.

j. Fertilizer is not the major nitrate source in the profile. The probable source of the nitrate is conversion of organic material in native sod to nitrate upon cultivation. No data is presently available to evaluate the present rate of conversion of organic material to nitrate or whether any of this nitrate is presently being lost below the root zone. A rate of nitrate leaching can be calculated. This rate is subject to severe assumptions and should be used with caution.

7. Other sites

   a. The nitrate levels in the water at the Newby site and the Gettle-Jones site are moderately low. At the Anderson and Bokma sites, the nitrate levels are moderately high.

   b. The Flesch site has very high nitrate levels in the water and in the material drilled.

   c. Although water analyses were not performed, the nitrate levels in the rock at the Skari site are alarmingly close to those at the Flesch site. Detailed nitrate evaluation of the ground water at the Skari site is warranted.

   d. The Claggett shale at the Skari site carries very high ammonium. This anomalous ammonium is not present in the till at the Skari site, but some ammonium is present in the till.

8. General conclusions with respect to the nitrate problem

   a. On the basis of the results at the Brickley-Hoagland site, the source of the nitrate is tentatively assigned to cultivation of native sod. This does not preclude the presence of high nitrate bedrock as a contributing source in areas of very high nitrate.

   b. Research on cultivation methods which eliminate or reduce rapid conversion of organic material to nitrate should be conducted. This research would apply particularly to areas in which native sod is being broken up.

c. The possible dangers of nitrate production by cultivation should be monitored in detail in areas where scalping and furrowing are being applied to native sod to improve over-grazed range (for example the Rohde site). If scalping is done every ten years, than a new surge of nitrate may be initiated with each treatment.

d. In areas where water is collected for stock use (or human consumption), farmers should be aware that evaporative or freeze concentration of the liquid can raise marginal nitrate levels to toxic levels. A simple semiquantitative nitrate test which can be used by farmers on a routine basis is needed.

e. Alfalfa may help reduce the nitrate levels in the profile to depths as great as 20 feet. Research is needed, however, to determine if cultivation of the alfalfa to prepare for a new crop produces a nitrate problem of lesser, equal or greater magnitude than before the alfalfa was introduced.

f. If humans (especially infants) are drinking high nitrate water, attention should be paid to the findings of Gruener, et al. 1970, who believe that Vitamin C aids in the prevention or cure of methemoglobinemia. If possible, water that does not contain nitrate should be found. Demographic studies of the possible effects of nitrate poisoning in eastern Montana might provide more insight into the nitrate problem.

9. There are severe problems with any technique used to determine the total ionic load (salt load), and exchangeable cations. The best procedure appears to be total leaching with potassium acetate. More

work will be done in this area.

10. Seismic refraction is not very useful for finding the groundwater table.

11. No correlation between bedrock lithology and saline seep was found, but work is continuing in this area.

12. The next step in delineating areas of potential seep should be to compare areas which are cultivated and have no seep with those that are cultivated and do have seep. More drill holes may be needed in this study.

IV. Future Plans

This study is being continued under the support of a Water Resources Research Allotment Grant. A limited study of the organic nitrogen levels at the Brickley-Hoagland site will be made to test the conclusions about the source and movement of nitrate. The nitrogen research will then be phased out, and work will turn toward the other ions. Some work on the comparison of areas that have saline seep with cultivated areas that do not will be continued. The objectives remain substantially the same as the work continues.

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INVESTIGATION OF SALINITY IN HYDROLOGICAL SYSTEMS IN MONTANA

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INVESTIGATIONS OF SALINITY
IN HYDROLOGICAL SYSTEMS IN MONTANA

SUMMARY AND CONCLUSIONS

Salinity problems have been identified in groundwater and surface water in 36 investigated Montana counties. In many areas saline seeps and salinity from irrigation water has degraded land and water resources. Evaluation of public water supplies indicate 12 communities using streams as a source of municipal water are presently or will potentially be impacted by salinity. Similarly, fourteen communities using groundwater are presently or will potentially be impacted by salinity.

Of the seeps, ponds, springs and streams examined, 79% do not meet drinking water standards or criteria of the U. S. Public Health Service (USPHS), Environmental Protection Agency (EPA), or the National Technical Advisory Board. Salinity related problems were most common in areas of extensive dry land farming operations. Irrigation related salinity problems also were present. These problems were found to have deleterious effects on surface and groundwater supplies. When available, comparison with present and past water quality records indicated many water quality changes have occurred in hydrologic systems in the past 10 to 20 years. Of the streams examined, the Musselshell River reflected substantial salinity increases. Other streams reflected minor salinity changes and for still others the data was inconclusive.

Groundwater degradation also was identified in a number of areas. The most dramatic water quality changes observed were in the communities of Denton and Coffee Creek where nitrate increases have seriously reduced the suitability of the water for human consumption.

The salinity problem is widespread in Montana and is expected to increase in the future. As salinity problems grow, so will losses of soil productivity and surface and groundwater resources will be further degraded. Groundwater pollution commonly is irreversible, resulting in permanent damage to the groundwater system. Long-term economic damage is occurring and is affecting individual land owners and the productivity of agricultural lands. Large gaps in awareness of the salinity problem also need correcting. The magnitude of the problem will not decrease and the problem will continue to increase.

Some current land uses are creating salinity problems and, if left unaltered, will pose economic and environmental problems to future generations. Implementation of abatement procedures, land use regulations, and sound land and water management programs are needed now to prevent additional degradation of land and water resources.

I. INTRODUCTION

This project was funded as part of a legislative appropriation to Montana Department of State Lands. The Water Quality Bureau undertook this effort at the request of the Department of State Lands.

Saline seep development is basically agriculturally caused and is related to a combination of topographic, hydrological, and geological factors. The relation of marine shales, e.g., Bearpaw, Claggett, and Colorado to saline seeps has been documented by Miller (1973). Mechanisms for the development of saline seeps are described by: Great Falls Workshop in Saline Seep (1971), Bahls and Miller (1973), and Krall (1974).

It is the intent of this project to provide documentation of saline water problems. This documentation can occur through field investigations and examination of water quality records. Compilation of this data will establish a quality baseline in areas of known or probable saline areas. The importance of establishing valid baseline data cannot be overlooked. Baseline data provides the means to identify and avoid potential problem areas.

By definition, saline waters are consistently high in dissolved solids. The predominant elements are: magnesium, calcium, sodium, sulfate, and chloride. Nitrates are most noticeable in seep-related water problems. Of these elements, sodium poses the greatest threat to soil productivity, while nitrate is a threat to domestic and municipal water supplies.

The hazardous effects of saline waters to livestock, poultry, and irrigation waters has been well documented by Heller (1930), Kelley (1939), EPA Water Quality Criteria (1973), and others.

Nitrate concentrations have been linked to stomach cancer (AWWA, 1974) and infant methemoglobinanemia (Armstrong, 1958). Thus, these waters may pose a threat to human health or they may be declared unfit for human consumption, causing economic problems for small communities needing potable water.

Sulfates have deliterious effects on plants (Scofield, 1935) and livestock (Allison, 1930). Diarrhetic effects to humans and livestock are provided by sulfates and sulfate salts.

Other common elements identified in saline water which may be toxic or in excess of standards to humans, plants, livestock, fish and wildlife are: fluoride, molybdenum, selenium, vanadium, iron, manganese, and nitrate.

Originally this report did not intend to include irrigation salinity problems. However, increasing evidence indicates irrigation practices are forming saline soils and degrading state waters. Irrigation practices produce saline problems through evapotranspiration, leaching of naturally saline soils, and excessive water usage. Excessive water placed on naturally saline soils solubilizes salts that are normally soil bound. These salts are left on the soil surface or washed back to the stream by return flows. The stream gradually accrues salts and deposits them on downstream irrigated lands where the process starts anew. Salt leaching also occurs downgrade from unlined irrigation ditches; consequently, adjacent areas are devoid of vegetation, and shallow wells become unusable. This problem is not unique to Montana; irrigation salinity problems exist on the Colorado River, Grand Valley, California, and numerous other locations. Irrigation and dryland salinity have two common denominators--extensive cost in rehabilitating salt-laden soils and waters and a disregard for future generations.

Livestock deaths, loss of soil productivity, degraded streams, and "sour" wells have been attributed to salinity problems. These problems are not limited to man's cultural sphere. Fish and wildlife are also susceptible to salinity affects.

Fish and wildlife losses have been reported from various locales. However, to document these cases and discuss each toxic element is beyond the scope of this report. Many of the elements previously mentioned are lethal to fish and wildlife. Until further evidence is obtained, it will have to suffice to note that deer deaths and loss of pond fisheries have been attributed to saline waters.

II. PROBLEM DESCRIPTION

The saline seep phenomena has recently been recognized as a major threat to agricultural productivity over large areas in Montana. Another less recognized, but equally important, problem is the long-term impact of saline waters on hydrologic systems. Specifically, the existing and potential impact on municipal water supplies, domestic and stock wells, ponds, reservoirs, springs and streams.

The portion of Montana that has been affected by saline seep generally is characterized by a relatively thin aquifer or alluvium of glacial origin underlain by a thick, virtually impervious shale or dense clay strata. These shallow aquifers provide water for municipalities, domestic uses, livestock and are sources for numerous springs, streams, and ponds. The potential exists for many waters in these shallow aquifers to be polluted by saline waters, and such pollution has been found in numerous areas. Shallow groundwater represents a valuable resource in many parts of Montana and economical alternatives to these water supplies do not exist.

Dryland seep problems originate from excess water in contact with salt-bearing strata After contact with these strata, the waters become salt laden and generally contain high nitrate concentrations. The salt-laden waters will either seep horizontally or, through capillary action, move vertically. The salts are generally deposited on the soil surface creating white residue and unproductive soils. A seep that has developed a surface water flow often ends up reaching a stream, pond or forms a saline spring. These waters have the capacity to degrade streams, lakes, ponds, domestic and municipal water supplies.

Reports and other investigators indicate this problem is growing and poses a major threat to potable water supplies and soil productivity.

It is commonly believed that salinity problems are endemic to dryland agriculture. However, salts originating from irrigation practices can cause the same problems as those emanating from dryland seeps. Irrigation salinity may be one of the most pressing problems facing water resources in Montana. In time, the economic penalty will be incurred by downstream water users. Current estimates indicate irrigation related salinity affects 120,814 acres; it is possible that Montana is blessed with too much low-cost water. This surplus tends to encourage abuse of a valuable resource in the form of excess water use and poor management. For the long-term benefit of future generations, this resource must be managed with great care.

Early Montana Water Resources Surveys (published by State Engineers Office, Helena) provided encouragement for irrigation projects. Statements such as "the lands are readily irrigable," provided an impetus for many irrigation developments. These statements were premature as water quality data, hydrogeological and soil analyses were grossly inadequate.

Thus, these early reports sometimes encouraged usage of marginal soils and waters, which were found to be deliterous to long-term soil productivity. Latter reports (Richland County, 1971) acknowledged a land classification system for irrigable lands and stated "any future project development should be based on a detailed study."

Drain tile, an accepted method for alleviating irrigation salinity problems, simply transfers the problem from the land to surface water and to downstream users. Drainage is a temporary cure which is best described by McGauhey (1967) when he stated, "We have learned to prevent the poisoning of land from our irrigation practice, we may go the way to Mesopotamia by poisoning the water instead." The problem facing water quality and land productivity resulting from irrigation salt accrual is best summed up by Ebert (1971), "No where else has there been more misuse and resource deterioration than in irrigation districts of arid lands."

Salinity problems are also associated with: overgrazing, oil and gas brines, poor coal reclamation practices and natural soil and geological conditions. Each salinity source is a unique problem with potentially far-ranging effects on water quality and soil productivity.

This project and other projects have found this data deficiency. There are reasons for this deficiency including expense in obtaining salinity data, the newness of many salinity problems, and the general lack of understanding of salinity. Casey (1972) described another possible cause of the scarcity of salinity data. He states:

> An irrigation scheme or a major water storage project such as a dam, may be a massive undertaking which consumes both economic and political capital. This in turn leads to an inability to admit mistakes in the planning and execution of the project, and may explain why it is so difficult to obtain hard data on so many problems in the salinity domain.

In the past few years, there is a growing awareness of the impact of salinity in hydrologic and agricultural systems in Montana. This problem has given rise to a demand for salinity data, and numerous programs are underway in Montana to examine the salinity problem. The basic assessment of salinity in Montana is and will continue to be significantly impaired by the lack of historical salinity data.

Currently, salinity investigations are being conducted by the Montana Bureau of Mines in conjunction with the Water Quality Bureau; Montana State University; the U. S. Agricultural Research Service; and the U. S. Bureau of Reclamation.

Erosion has been overlooked as a salinity related problem. Frequently saline saturated soils will support little or no vegetation; thus, increasing erosion rates. This lack of vegetation coupled with water saturated soils (which tend to slump) may be increasing the sediment loads in many Montana streams. Saline seeps often appear near coulees or other steep embankments. These areas are subject to severe erosion and without needed vegetation covers, the erosional process is accelerated and unabated; which results in streams carrying abnormal sediment loads and loss of valuable soil.

The impacts of salinity problems--regardless of cause--will be felt in domestic and municipal water supplies, reduced soil productivity, degraded surface water, useless irrigation waters, loss of livestock water supplies, and increased erosion. Salinity and its associated problems are rapidly increasing and current abatement practices are token in scale.

The full impact of Montana's salinity problems has yet to be felt. Continued and rapidly expanding use of marginal lands for farming combined with poor soil and water conservation practices will clearly accelerate Montana's salinity problems.

III. MATERIALS AND METHODS

Sites selected for water sampling were based on information from: Montana Department of State Lands, Montana Fish and Game personnel, personal communication with farmers and ranchers, information solicited from district Soil Conservationists, and aerial surveys by Water Quality Bureau personnel.

Information from early USGS water supply papers provided sampling sites, some of which were resampled, that were infrequently amenable for resampling. Other records examined were: Water Quality Bureau files, miscellaneous livestock water reports and miscellaneous well log data. Examination of historical records (for resampling purposes) were generally unproductive because of: (1) dates or locations were often omitted in early records; (2) wells were often abandoned; (3) sample analyses were often incomplete.

Based on this information and records, sampling was done in 28 different counties and at different sites within those counties. No samples were taken in the 12 counties that reported no saline-affected acreage.

Soils descriptions and geological formations were included to provide information on additional factor(s) which influence water quality. Where possible the descriptions are given at the water sampling sites. Soils information originated from: Soils Survey the Upper Musselshell Valley (USDA 1943); Soils of Meagher County (USDA 1944); Soils of Stillwater County (USDA 1957); Soils of Golden Valley (USDA 1942); Soils Survey Central Montana (USDA 1953), etc. and personal communications with area soil conservationists. Geological features were taken from: Geologic Map of Montana compiled by Ross et al, Bureau of Mines and Geology, 1955.

Saline-affected acreages (Tables 3 and 4) are estimates compiled by the Montana Department of State Lands. The estimates are from state soil conservation districts.

Chemical analyses were done by the Department of Health and Environmental Sciences (DHES), Water Quality Bureau's chemistry laboratory. Analytical methods were in accordance with Standard Methods for the Examination of Water and Wastewater (1971).

IV. MONTANA AGRICULTURE AND SALINITY

As described in a recent Bureau of Reclamation report (Anon, 1975), early irrigation on private lands in Montana began in the late 1800's. The Reclamation Act of 1902 allowed large-scale government assisted irrigation projects. The report further states:

> "Land problems, alkalinity, salinity, drainage, etc. were not long in developing on USBR projects."

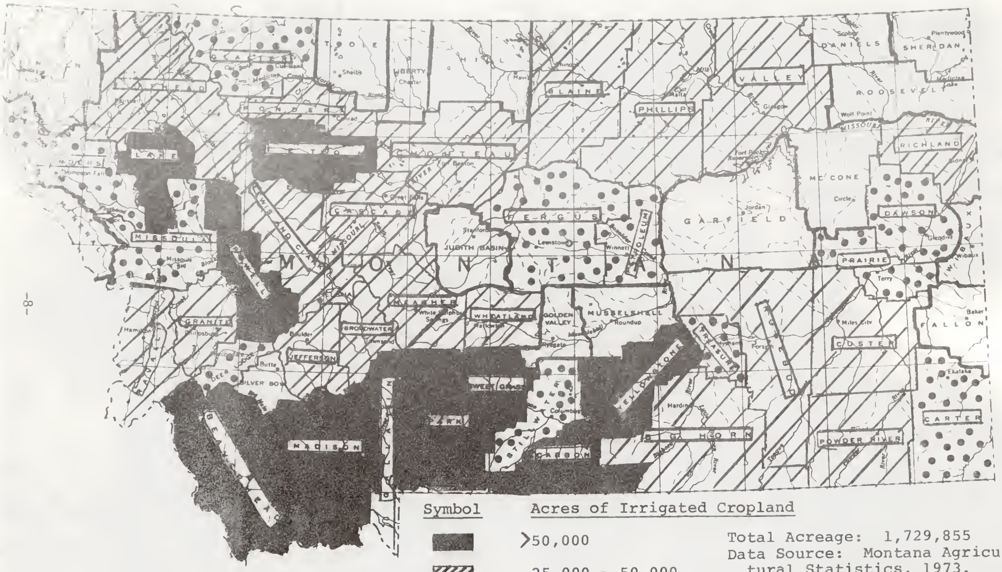
In the Omnibus Act of 1926, irrigation damaged land for 3 areas in Montana - Huntley, Milk River and Fort Shaw (Greenfields Unit), showed of the 135,137 irrigated acres, 17,921 acres (13%) were permanently lost and 32,826 acres (24%) had reduced capability. (Anon, 1975). Nearly four of every ten irrigated acres were having severe salinity problems!

Irrigation development continued and in 1973 there were an estimated 1,729,855 irrigated acres in Montana (Montana Crop and Livestock Reporting Services, 1974). This did not include lands that were sub-irrigated nor lands such as irrigated pasture, from which a crop was not mechanically harvested. Estimates by DNRC (Montana Department of Natural Resources and Conservation) (G. Smith, DNRC, July 1975) indicates a total of 2,231,127 irrigated acres in Montana in 1975 (exclusive of Missoula and Mineral County). The distribution of lands by county (Figure 1) shows the southwestern and west central areas of Montana to be the major irrigated area in the state.

There is approximately four times as much dry cropland (7,226,900 acres) as irrigated cropland (1,729,855 acres) in Montana. The distribution of non-irrigated cropland in Montana (Figure 2) shows the north and northeast parts of Montana to be the principal dryland crop area.

Irrigation by sprinklers is a relatively recent development in Montana. Use of sprinklers on lands in Montana is increasing rapidly; however, there is little information on acreage sprinkled. The Department of Natural Resources and Conservation concluded that there were 259,763 acres irrigated by sprinklers in 1975. (Glen Smith, Soil Scientist, DNRC unpublished data, July 1975). Salinity problems of sprinkler irrigated land have not been examined. Due to high operating costs, excess water beyond crop requirements is normally not supplied to sprinkled lands. Return flows and groundwater seepage probably are substantially less. Buildup of salts in the soil surely occurs, but the impacts are poorly known.

Of great concern both economically and environmentally is the impact of salinity from agriculture. Loss of valuable cropland and pollution of water systems are two important consequences of the salinity increases. As described by Miller (no date) and Miller and Bahls (1973) and discussed by Harlow (1974), dryland areas affected by salinity are rapidly increasing. Saline seep affected lands by date are as follows:



Symbol	Acres of Irrigated Cropland
■	>50,000
▨	25,000 - 50,000
⁘	10,000 - 25,000
☐	<10,000

Total Acreage: 1,729,855
Data Source: Montana Agricultural Statistics, 1973. Montana Department of Agriculture.

Note: Does not include irrigated pasture land.

Figure 1. Irrigated Cropland Harvested in Montana in 1973 by County.

Date	Estimated Acreage Affected	
1969	55,700	SCS Estimate
1971	81,430	" "
1973	152,500	" "
1974	140,485-142,585	Dept. of State Lands

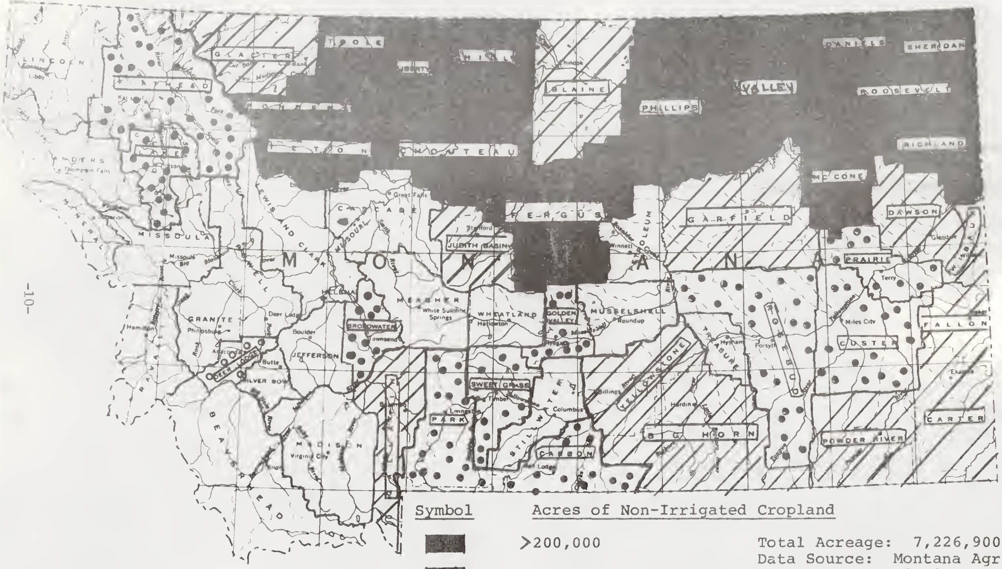
These acreage estimates will require field evaluation and evaluation of damage criteria to insure a uniformity in reporting. Based on 1973 cropland estimates and 1974 damage estimates, approximately 2 percent of Montana's dryland crop area is damaged by salinity. Distribution of the damaged acreage (Figure 3) shows the north central and northeast portions of the state to be most severely damaged. Madison and Stillwater Counties, however, reported substantial salinity damaged acreage. The growth of salinity damaged land is rapid and represents a significant economic burden to the individual landowners and a significant environmental problem to the public.

The impact of salinity damaged irrigated lands, particularly during the last twenty years is poorly known. Although there have been massive government economic assistance in land and irrigation development, there have been, until the past few years, only token efforts to study the environmental consequences of these developments. In 1974, the U. S. Department of Agriculture County Committees for Rural Development estimated that 120,814 acres or about 7% of Montana's irrigated lands had been damaged by salinity. The statewide distribution of this land (Figure 4) shows a number of areas in the state to have salinity damaged irrigated land. The estimates need field examination to confirm the affected land areas and to insure uniformity in reporting. Although salinity damaged irrigation land is thought to be increasing, the rate of increase is poorly known.

The rate at which native lands are converted to dryland or irrigated cropland is important to the salinity problem. There are rumors that land areas ranging from 0 to 500,000 acres are converted to cropland yearly. Mr. Leo Kolstad, Agricultural Stabilization and Conservation Service, estimated 75,000 to 100,000 acres of additional cropland in Montana in 1975 (telephone communication July 1975). The DNRC has projected on the basis of red meat demands, the following future irrigation needs in Montana:

Year	Additional Irrigated Acres
1980	216,046 - 642,045
1990	432,092 - 1,284,091
2000	648,139 - 1,926,136
2020	1,080,231 - 3,210,227

Impact of additional irrigated acreage on water quality in Montana could be enormous. Water used for irrigation depletes streams and water returned to the streams is usually degraded in quality. Some new irrigated lands will probably be salt-rich and marginal for irrigations.

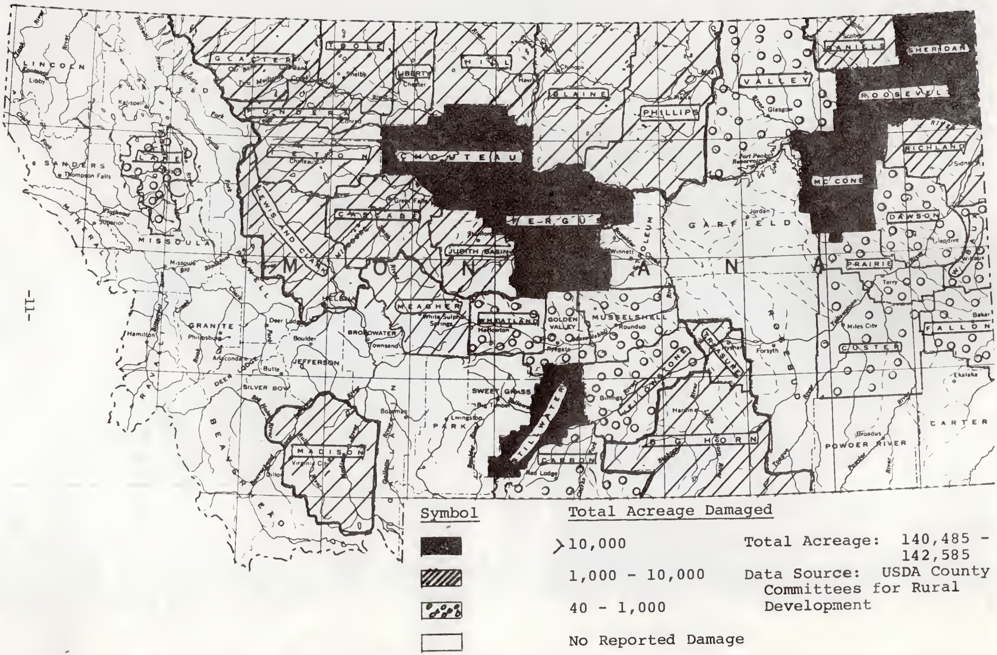


Symbol	Acres of Non-Irrigated Cropland
■	>200,000
▨	75,000 - 200,000
⁙	25,000 - 75,000
□	<25,000

Total Acreage: 7,226,900

Data Source: Montana Agricultural Statistics, 1973. Montana Department of Agriculture.

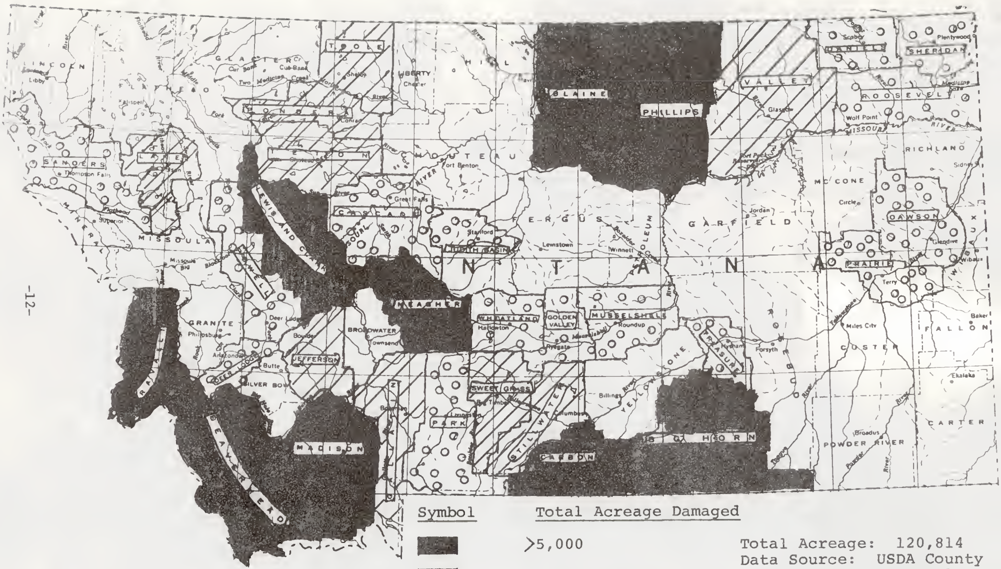
Figure 2. Non-Irrigated Cropland Harvested in Montana in 1973 by County.



Total Acreage: 140,485 - 142,585

Data Source: USDA County Committees for Rural Development

Figure 3. Dryland Acres Damaged by Salinity in Montana by County.



Symbol	Total Acreage Damaged
■	>5,000
▨	800 - 5,000
○	20 - 800
☐	No Reported Damage

Total Acreage: 120,814
Data Source: USDA County Committees for Rural Deve ment.

Figure 4. Irrigated Acres Damaged by Salinity in Montana by County.

Increases in irrigation acreage probably will lead to significant additional degradation of water quality in many streams and lakes in Montana.

To appraise the present impact of salinity from agricultural lands on streams, the following analysis was made:

1. The average annual dissolved solids load was calculated for the Missouri River at Culbertson and the Yellowstone River at Sidney. This includes all of Montana east of the Continental Divide. Based on USGS water quality records for 1973, there are about 9,695,000 tons per year of dissolved solids exiting this region annually.

2. Based on information from DNRC and data compiled by the Montana State Lands Department, there is about 1,944,000 acres of irrigated land and 7,091,000 acres of dry cropland in the area.

3. A commonly used value for salinity increases in irrigation water is 1/2 to 1 ton/acre/season, there is 1,458,000 tons/year of dissolved solids produced from irrigated lands or about 18% of the total salt load in the river systems.

4. If it is assumed that dry cropland contributes 1/10 as much salinity as irrigated lands, it is calculated that 532,000 tons/year of dissolved solids are produced by dry cropland. The combined effects of irrigated and dry cropland salinity is equal to about 26% of the total salt load in the river systems. (Figure 5 shows anticipated salt load vs. time).

5. If 50 percent increase in irrigated acreage and an additional 2,500,000 acres of dry cropland are developed by the year 2000, increased salinity will occur. The increased salt yield from this land (assuming the same salt yields as above) will cause 38% of the salt load of the Yellowstone and Missouri Rivers to be the result of farming practices.

This analysis obviously has many assumptions, however, the analysis suggests that salinity in stream systems may be significantly impacted by farming, particularly by irrigated lands. Future water diversions will come from the streams causing further depletion of flows. This depleted flow will carry salt, the additional salt load, thus, further increasing the stream salt concentration.

Salinity is only one detrimental water quality parameter associated with irrigation and farming. Pesticides, nutrients, suspended sediment and temperature increases all degrade water quality and all are produced by agricultural lands. Impacts of these constituents on streams is poorly known. The impacts depending on stream and irrigation return flow and quality ranges from slight degradation of the stream to complete destruction of the aquatic ecosystem.

Salinity increases not only impact the aquatic ecosystem, but also creates problems for domestic water users and is detrimental to use of water for irrigation. A recent EPA publication on salinity (EPA, 1974) states:

> "Salinity created by irrigation generates additional problems for the downstream user. Saline water may increase the salinity of the root zone environment of the soil. Elevation of soil salinity may inhibit seed germination, reduce crop yields and prevent the growing of crops having low salt tolerances. In extreme instances, salt buildup may even cause the removal of land from agricultural production...."
>
> "As the salinity of applied water increases, a larger quantity is ordinarily needed to prevent salt buildup in the root zone. In some soils continued irrigations using limited amounts of water--only that necessary to maintain field capacity--will invariably induce salt concentration. The buildup can progress to the stage where it adversely affects the surface and greatly inhibits plant growth, creates large "kill" areas and may ultimately result in the abandonment of much land."

Several conclusions and recommendations can be made relative to salinity impacts on stream systems. These are:

1. Salinity from agriculture is probably a significant factor in the salt loads of streams in Montana. Future increases in cropland particularly irrigated cropland will further increase salinity problems in state waters including groundwater.

2. The impacts of increased salinity on aquatic ecosystems is poorly known. This aspect of stream salinity needs investigation. Additionally, the impact of salinity on other beneficial water uses, such as municipal and domestic water supplies and irrigation, needs to be determined.

3. Salt yields from croplands - particularly irrigated lands needs evaluation. The current investigation by the Bureau of Reclamation (BuRec) in irrigation includes some measurements of salinity and suspended solids. These efforts, however, are not major in scope and some data is not available to the public or to other agencies.

4. Salt balances in heavily irrigated drainages should be evaluated in detail to understand the movement of dissolved materials in the hydrologic system.

5. The present and future impact of salinity on hydrologic systems needs to be examined to determine what "costs" are associated with the benefits of crop production. These "costs" should include environmental as well as economic costs.

6. Future lands to be irrigated need be examined to determine salinity conditions that may be created by irrigation.

7. Techniques to minimize salt accumulations in state waters from croplands should be determined and field tested.

8. Other parameters such as suspended solids, pesticides, nutrients, and temperature associated with water from farming should be evaluated to determine their impact on hydrologic systems.

9. A water quality monitoring network is needed to determine trends in salinity in hydrological systems. Present water quality monitoring is inadequate to determine salinity changes in most hydrological systems including streams, lakes, and groundwater bodies.

10. Water management programs must be developed which measure irrigation water usage provide minimal flows to saline impacted streams, encourage economical water use, and minimize or eliminate saline return flows.

11. Development of an adequate biological data base which will show environmental changes not depicted by chemical analysis.

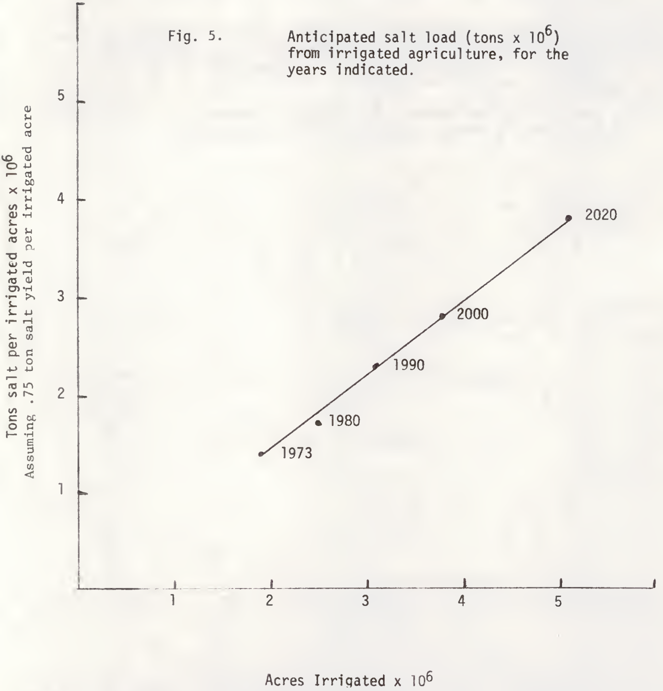


Fig. 5. Anticipated salt load (tons x 10^6) from irrigated agriculture, for the years indicated.

Based on Projected DNRC Irrigated Land Needs for Red Meat Production in Montana

V. WATER QUALITY STANDARDS

Clean water is the lifeline for survival. From this standpoint, it is necessary to understand water quality standards and how they pertain to this survey. The following narrative describes water quality standards and their significance.

References to water salinity and alkali hazards are based on Saline and Alkali Soils (USDA No. 60, 1954). Figures 7 and 8 show water samples during this survey and their classification as irrigation waters. This classification is based on sodium absorption ratio (SAR) and specific conductance. Sodium adsorption ratio is basically a ratio of sodium to calcium and magnesium ions. The experiments cited by U. S. Salinity Laboratory show that the SAR value predicts reasonably well the degree to which irrigation water tends to enter cation exchange reactions in soil. High values for SAR (>6) imply a hazard of sodium replacing calcium and magnesium in the soil; this replacement is damaging to soil structure. This exchange process results in poor soil permeability.

Terms for waters of high dissolved solids are taken from Study and Interpretation of the Chemical Characteristics of Natural Waters (USGS, 1970).

	Dissolved Solids mg/l
slightly saline ----------------	1,000-3,000
moderately saline ----------------	3,000-10,000
very saline ----------------	10,000-35,000
briny ----------------	$>35,000$

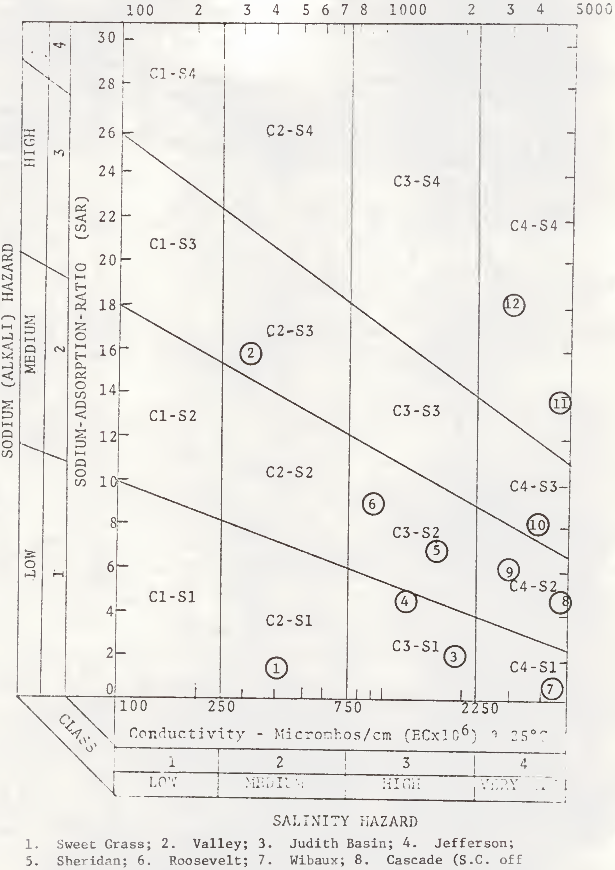
An early study by Heller (1930) showed that high salt concentrations (e.g., 15,000 mg/l SO_4 and 10,000 ppm $CaCl_2$) caused retarded growth and mortality among young test animals. Dissolved solids (e.g., sodium chloride) of 20,000 mg/l causes anorexia, weight loss, dehydration and collapse in livestock (Water Quality Criteria, 1973).

References to salinity effects are shown in Table 2. This classification is based on total dissolved solids and specific conductance values. A total dissolved solids (TDS) concentration greater than 2,000 mg/l (Table 2) requires careful management practices (irrigation purposes). Livestock waters containing greater than 7,000 mg/l TDS should be avoided; however, reports indicate animals may subsist on these waters. Poultry requires waters containing less than 5,000 mg/l of TDS (Table 2).

Table 3 is a compilation of different organizations' water quality standards. This table is pertinent to domestic and municipal supplies. These are only recommended standards, and problems may be variable due to changeable water chemistry and type and amount of usage. Residents of many Montana communities have developed tolerances to waters in excess of these standards.

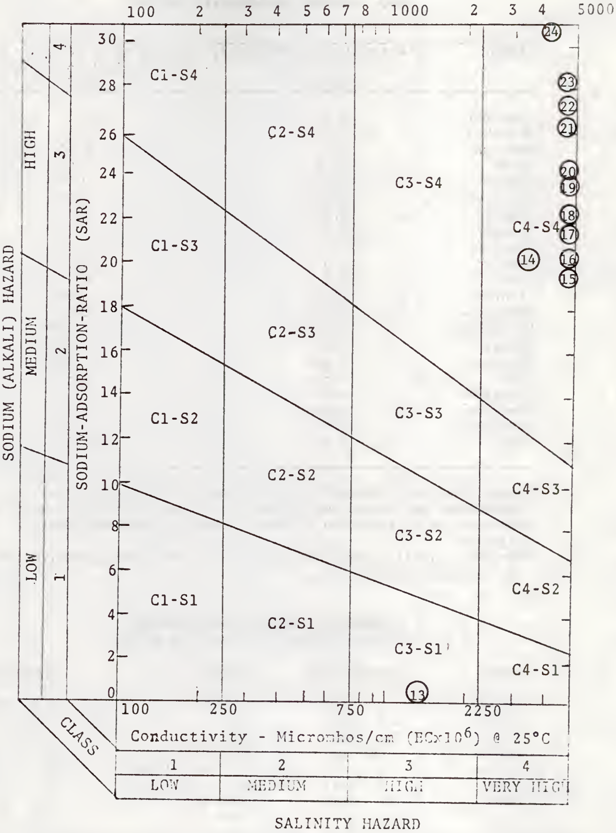
Table 1 is recommended maximum concentrations of trace elements in irrigation and livestock waters. During this survey, nearly all of these trace elements were identified often in excess of recommended beneficial concentrations. These recommended concentrations are considered guidelines, and harmful effects from excessive concentrations will vary depending on the chemical interactions. In some cases, the toxicity will be lessened, and in other waters the toxicity will be enhanced. In high concentrations sulfate may cause the precipitation of calcium and may themselves be toxic to plants (Kelly, 1939). According to Scofield (1935) waters with over 960 mg/l sulfates would be unsuitable for irrigation. Allison (1930) reported cattle weakening and eventually dying while continually drinking water in excess of 3,590 mg/l sulfate.

Figure 7. Depicting Waters Hazardous for Irrigation Use. One Location per County. Graph from USDA Handbook No. 60.



1. Sweet Grass; 2. Valley; 3. Judith Basin; 4. Jefferson; 5. Sheridan; 6. Roosevelt; 7. Wibaux; 8. Cascade (S.C. off scale): 9. Blaine; 10. Rosebud; 11. Carbon;(S.C. off scale); 12. Prairie.

Figure 8. Graphical Depiction of Waters Hazardous for Irrigation. One Location per County. Graph from USDA Handbook No. 60.



13. Madison (SAR off scale); 14. Glacier; 15. Fallon*; 16. Liberty*; 17. McCone*; 18. Yellowstone; 19. Musselshell*; 20. Petroleum*; 21. Phillips; 22. Fergus; 23. Richland; 24. Stillwater.

* Specific Conductance off scale. Samples collected from Custer, Daniels, Teton, Toole Counties exceeded both scales.

Table I

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATERS[a]

Element	For Waters Used Continuously on All Soil (mg/l)	For Use up to 20 Years on Fine Textured Soils of pH 6.0 - 8.5 (mg/l)
Aluminum	5.0	20.0
Arsenic	0.10	2.0
Berylium	0.10	0.50
Boron	0.75	2.0
Cadmium	0.010	0.050
Chromium	0.10	1.0
Cobalt	0.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5[b]	2.5[b]
Manganese	0.20	10.0
Molybdenum	0.010	0.050[d]
Nickel	0.20	2.0
Selenium	0.020	0.020
Tin[c]	-----	------
Titanium[c]	-----	------
Tungsten[c]	-----	------
Vanadium	0.10	1.0
Zinc	2.0	10.0

[a] These levels will normally not adversely affect plants or soils.

[b] Recommended maximum concentration for irrigating citrus is 0.075 mg/l.

[c] See text for a discussion of these elements - EPA Water Quality Criteria,

[d] For only acid fine textured soils or acid soils with relatively high iron oxide contents.

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN LIVESTOCK WATERS

Element	Concentration	Element	Concentration
Aluminum	5 mg/l	Fluorine	2.0 mg/l
Arsenic	0.2 mg/l	Lead	0.05 mg/l
Boron	5 mg/l	Mercury	0.01 mg/l
Cadmium	0.050 mg/l	Molybdenum	-----
Chromium	1.0 mg/l	Nitrate Nitrogen	100 ppm
Chromium	1.0 mg/l	Nitrite Nitrogen	10 ppm
Cobalt	1.0 mg/l	Selenium	0.05 mg/l
Copper	0.5 mg/l	Vanadium	0.1 mg/l
		Zinc	25 mg/l

Reference: EPA Water Quality Criteria, 1973.

Table 2

RECOMMENDED GUIDELINES FOR SALINITY IN IRRIGATION WATER

Classification	TDS mg/l	EC mmohs/cm
Water for which no detrimental effects are usually noticed	500	0.75
Water that can have detrimental effects on sensitive crops	500-1,000	0.75-1.50
Water that can have adverse effects on many crops; requires careful management practices	1,000-2,000	1.50-3.00
Water that can be used for tolerant plants on permeable soils with careful management practices	2,000-5,000	3.00-7.50

GUIDE TO THE USE OF SALINE WATERS FOR LIVESTOCK AND POULTRY

Total soluble salts content of waters (mg/l)	Comment
Less than 1,000	Relative low level of salinity. Excellent for all classes of livestock and poultry.
1,000-2,999	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry.
3,000-4,999	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing water feces, increased mortality, and decreased growth, especially in turkeys.
5,000-6,999	Can be used with reasonable safety for dairy and beef cattle, for sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
7,000-10,000	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
Over 10,000	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

Reference: EPA Water Quality Criteria, 1973.

TABLE 3

Selected water quality criteria and standards as compiled by four sources: Public Health Service (PHS), "Drinking Water Standards"; Environmental Protection Agency (EPA), "Public Water Supplies"; National Technical Advisory Board (NTAB), "Surface Water Criteria for Public Supplies"; and California State Water Quality Control Board (CWQCB), "Water Quality for Livestock." Concentrations are given as milligrams per liter, temperature in degrees centigrade, turbidity in JTU, and bacteria as number per 100 ml (va -- virtually absent; sat -- near saturation; vary -- variable, dependent on sampling technique or temperature; ap -- approximately).

	PHS	EPA	NTAB		CWOCB	
Constituent	Standard	Recommendation	Permissible Criteria	Desirable Criteria	Threshold Concentration	Limiting Concentration
Temperature			24			
pH		5-9	6-8.5		6-8.5	5.6-9.0
Dissolved Oxygen			3	sat		
Fecal coliforms	vary	2000	2000	20		
Turbidity	5		75	va		
Dissolved solids	500		500	200	2500	5000
Nitrate	45	ap 60	ap 60	va		
Bicarbonate					500	500
Calcium					500	1000
Chloride	250	250	250	25	1500	3000
Fluoride	vary	vary	vary	vary	1.0	6.0
Magnesium					250	500
Sodium					1000	2000
Sulfate	250	250	250	50	500	1000
Arsenic	0.01	0.1	0.05	none	1.0	
Boron			1.0	va		
Cadmium	0.01	0.01	0.01	none	5	
Chromium	0.05	0.05	0.05	none		
Copper	1.0	1.0	1.0	va		
Iron	0.3	0.3	0.3	va		
Lead	0.05	0.05	0.05	none		
Manganese	0.05	0.05	0.05	none		
Mercury		0.002				
Zinc	5.0	5.0	5.0	va		

VI. ANALYSIS OF STREAM SALINITY

Past water quality data collected from state streams appeared to offer a good opportunity to determine trends in stream salinity. The most complete set of water quality records for Montana are those of the U.S. Geological Survey. Streamflow and water quality records are available from other sources but they are less available and substantially less complete than those of the USGS.

To determine which stream records should be examined, a comprehensive list of streams known or thought to be influenced by salinity was compiled. Criteria used to determine salinity problems were:

1. Streams that were designated in Water Quality Bureau, water quality inventories and management plans as having salinity problems.
2. Streams located in glaciated areas that are underlain by marine shale formations.
3. Streams consistently having high conductivities (over 2,500 umhos/cm @ 25^oC).
4. Streams affected by unnatural discharges of saline water such as Lake Bowdoin into Beaver Creek and Priest Lake into the Marias River.
5. Streams that are receiving significant quantities of irrigation return flows from saline soils.
6. Streams which were mentioned as saline by state, federal, local organizations or private individuals.
7. Streams exhibiting high concentrations of dissolved constituents such as nitrates, metals, sodium, and sulfates.

Using these criteria the following streams are delineated (listed by drainage basin) and shown on map (Appendix J).

Lower Missouri River Basin

Poplar River, East Fork Poplar River, West Fork Poplar River, Redwater River, Second Hay Creek, Sheep Creek, Big Muddy Creek, Lake Creek, Missouri River near Wolf Point.

Milk River Basin

Sage Creek, Milk River, Beaver Creek, Laird Creek.

Marias River Basin

Hilger Coulee, Priest Butte Lakes and adjacent tributaries, Rocky Coulee, Teton River downstream of lake discharge, Cut Bank Creek, Marias River downstream of Hilger Coulee.

Musselshell River Basin

Painted Robe Creek, North Willow Creek, Mud Creek, Yellowwater Creek, Big Coulee Creek, Careless Creek, Current Creek, Box Elder Creek, Flatwillow Creek, Musselshell River from Shawmut to Missouri confluence.

Upper Yellowstone River Basin

Yellowstone River, Clarks Fork Yellowstone River, Shields River.

Lower Yellowstone River Basin

Sunday Creek, Sand Creek, Mizpah Creek, Sheep Creek, Sandstone Creek, Pennel Creek, Cabin Creek, the latter two streams are affected by oil well brines. O'Fallon Creek, Hay Creek, Lone Tree Creek, and Cedar Creek.

Middle Yellowstone River Basin

Hanging Woman Creek, Pumpkin Creek, Little Porcupine Creek, Armells Creek, Soap Creek, Rotten Grass Creek, Beauvais Creek, Pass Creek, Owl Creek and Pryor Creek, Tongue River at Miles City.

Middle Missouri River Basin

Arrow Creek, Coffee Creek, Wolf Creek, Dry Wolf Creek, Judith River (segments), and Sage Creek.

Undoubtedly there are other streams, particularly small and intermittent streams, that have salinity problems that should have been included on this list, but were not due to time and manpower limitations. Similarly, some streams or segments of streams on this list may subsequently be found, in future work, to have little or no salinity problems. The list probably does represent a good estimate of streams affected by salinity in Montana.

The next logical step in evaluation of stream salinity was to review available water quality information to see if sufficient data exists to determine the time trends in salinity. As mentioned previously, all available historical U. S. Geological Survey streamflow and water quality records were reviewed for this purpose. Based on this review, sites on the following streams had sufficient data to allow a salinity trend analysis: Musselshell River at Mosby (Fig. 17-20),Tongue River at Miles City (Fig. 13-16),Missouri River at Wolf Point (Figure 11), Milk River at Nashua and Harlem (Figure 12), and Yellowstone River at Billings (Figure 9).

Although USGS water quality records extend back at least 25 years and a large number of sites have been sampled, there are few sites for which there is sufficient data for a salinity trend analysis.

Reasons for the scarcity of suitable sites are:

1. No monitoring sites were located on streams affected by salinity.

Figure 9. Yellowstone River at Billings showing monthly Total Dissolved Solids Load vs. Monthly Streamflow

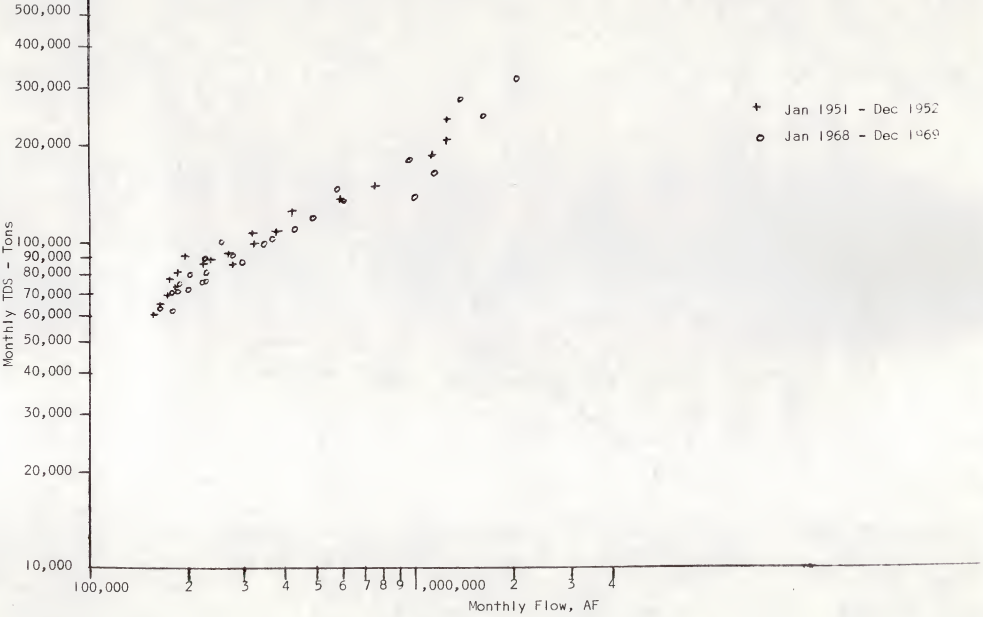
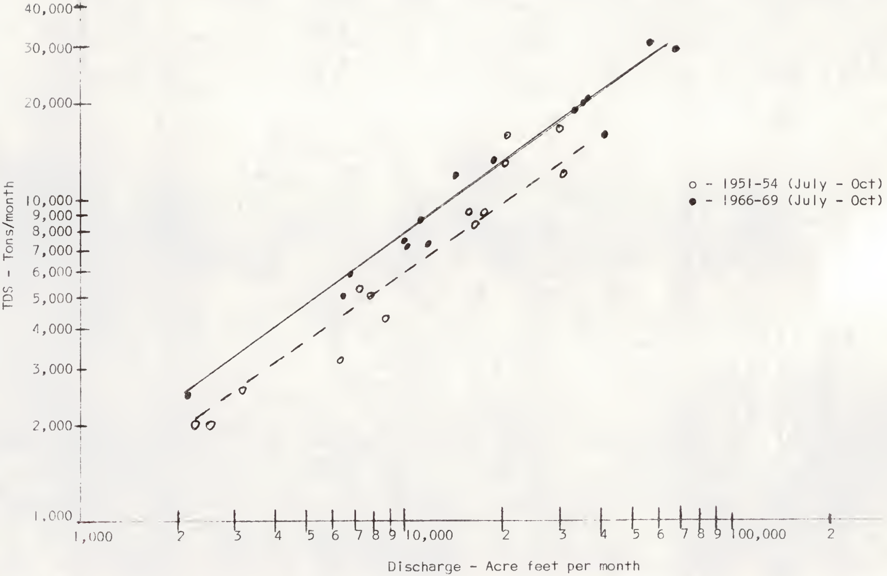


Figure 10. Tongue River at Miles City showing monthly dissolved solids load vs. streamflow.



2. Length of record was so short that any meaningful trend could not be determined (minimum records of five years are needed).

3. Data collected were not appropriate for a salinity analysis. Either streamflows or water quality data were missing or insufficient.

Four methods can be used to assess changes in stream salinity with respect to time. None are rigorous "proofs" of change, but rather techniques of examining records for indications of salinity trends. Care must be exercised in all cases to avoid misinterpretations. It is not proper, for example, to compare a "dry" year with a "wet" year, or data collected "before" and "after" construction of a dam above a station, or June data with October data.

1. Monthly loads and streamflow. Where data have been reduced to monthly values, a plot of monthly total dissolved solids load vs. monthly flow on log-log paper often will approximate a straight line. By plotting values for different periods of time, changes in the basic relationship may be apparent. Data from the Yellowstone River at Billings (Figure 9) indicates no apparent differences between data for 1951-52 and that for 1968-69. A possible increase in salinity for the Tongue River at Miles City during the period 1951-54 to 1966-69 is noted (Figure 13). Only July, August, September, and October data, representing the period when irrigation return flow would be most significant, were used for the Tongue River analysis.

   Ideally, a linear regression equation could be fitted to the two sets of data in the form $TDS=B\ Q^a$ or, on log-log paper, $\log TDS=\log b + a \log Q$. Statistical tests can then be performed to test for significant differences between the equations. Often, a cursory examination of the plots will reveal obvious changes or lack of changes.

2. Concentration vs. monthly flow. This method is similar to the first method except that average monthly concentration is plotted instead of monthly load. Scatter of the plotted points is greater than for method 1.

3. If monthly values have not been computed, data can be plotted (on a log-log graph) directly from USGS records, using either concentration in mg/l or load in tons per day versus mean discharge in cfs. Normally, these values are reported as composites for periods of from one to 30 days. Concentration (TDS) vs. discharge and load vs. discharge for two "dry" water years, 1954 and 1966 for the Tongue River at Miles City, is shown in Figures 13and 14. Figure 15is TDS vs. Q for 1952 and 1969. A slight increase in salinity is suggested by the data, but it is not conclusive.

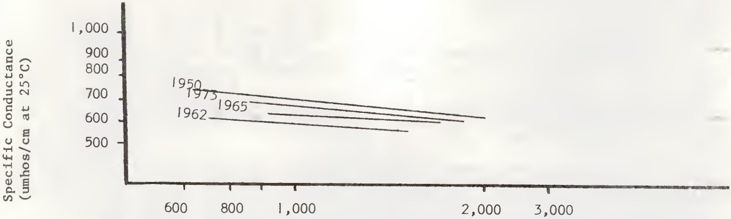


FIGURE 11. SPECIFIC CONDUCTANCE VERSUS STREAMFLOW FOR MISSOURI RIVER AT WOLF POINT

Selected Data from USGS Water Quality Records.

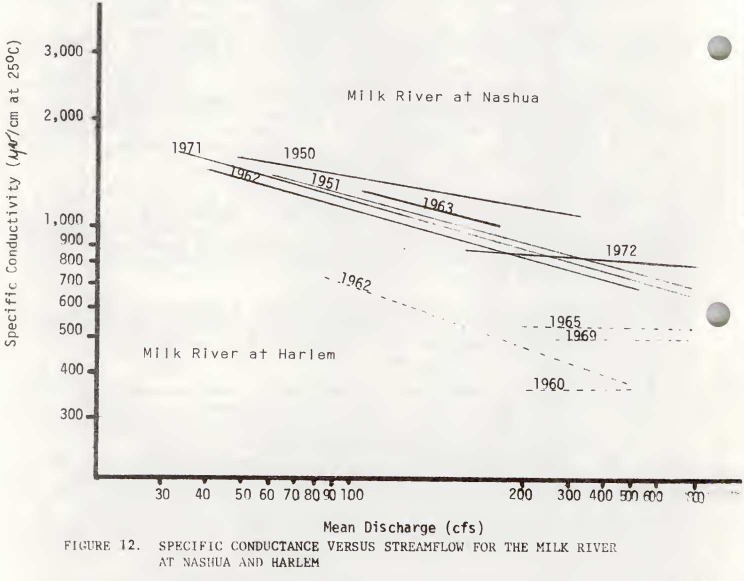


FIGURE 12. SPECIFIC CONDUCTANCE VERSUS STREAMFLOW FOR THE MILK RIVER AT NASHUA AND HARLEM

Selected Data from USGS Water Quality Records. Season of Record Predominantly During Irrigation Season.

Figure 13. Tongue River at Miles City showing Total Dissolved Solids Concentration vs. Average Stream Discharge.

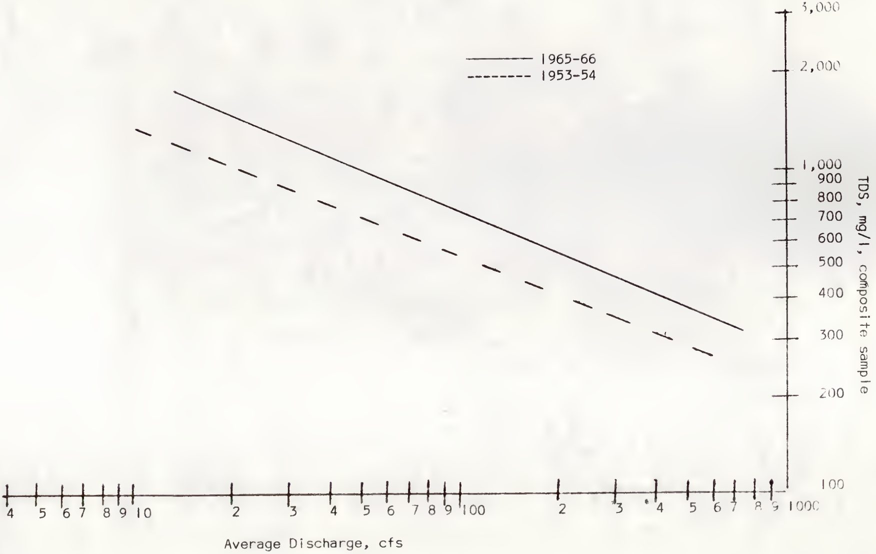


Figure 14. Tongue River at Miles City Showing Dissolved Solids vs. Streamflow.

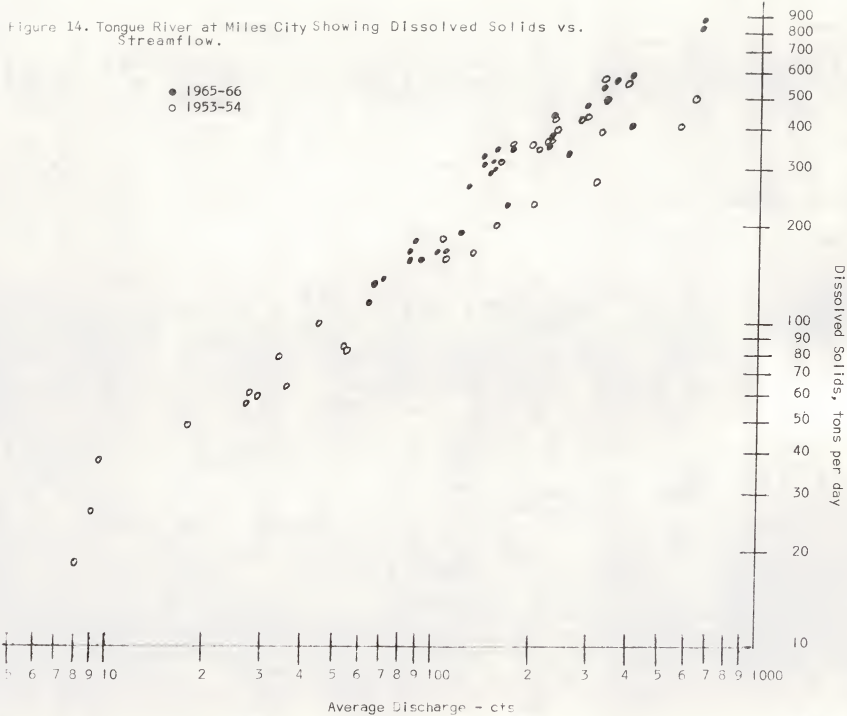
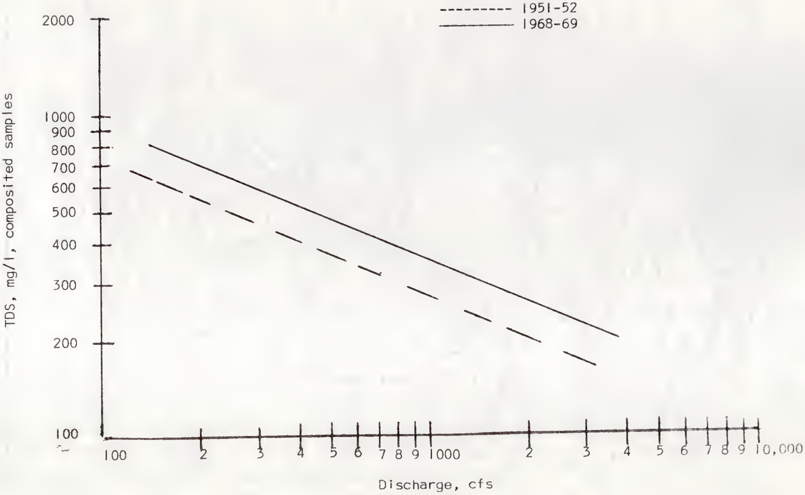


Figure 15. Tongue River at Miles City Showing Total Dissolved Solids Concentration vs. Discharge



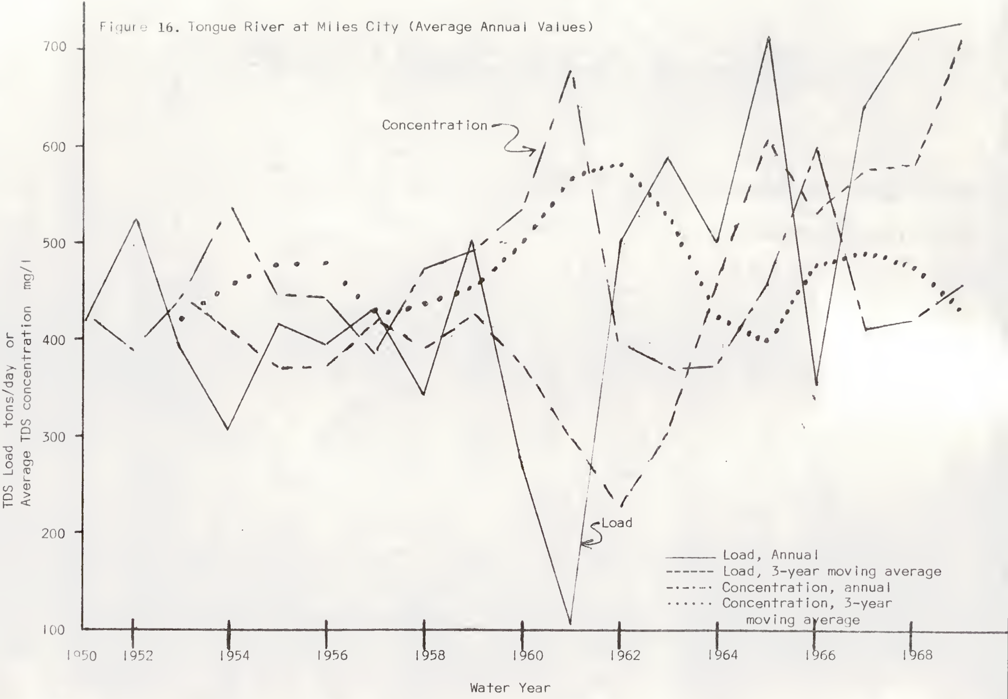


Figure 16. Tongue River at Miles City (Average Annual Values)

4. Until 1969, USGS records reported annual "weighted average" values for dissolved solids. These values could be plotted vs. time for a rapid evaluation. Since concentration naturally varies, care must be used to avoid misinterpretation. Wet weather cycles tend to produce lower concentrations of dissolved solids than dry cycles; thus, one must be aware of the runoff pattern during the period of analysis and not mistake changes in salinity for changes in precipitation and resultant runoff.

Figure 16 is a plot of annual average values of TDS (in mg/l and tons/day) vs. time from 1950-69. Superimposed on this plot, in order to smooth the annual fluctuations, is the 3-year moving average. Interpretation, in this case, is complicated by the extremely dry year of 1961.

All of the above methods could be applied to a specific ion, such as sodium or calcium, in order to detect changes in the relative concentration of dissolved minerals. Sodium adsorption ratio (SAR) could also be used as an indicator of shifts in salinity.

Method 1, monthly loads vs. monthly flow, analyzed statistically for regression coefficients and significant differences, is the preferred method in most instances, but it involves considerable effort. Method 3, illustrated by Figure 15, and analyzed statistically would be equally as valuable. Regression equations can, of course, be fitted to the other methods. The analysis can also be restricted to certain periods of the year, such as the irrigation season.

A plot of specific conductivity vs. flow (Method 3) for the Missouri River at Wolf Point shows no distinct trend in salinity.

Data shown are typical of the streams salinity records. It is virtually certain that the Missouri has increased in salinity due to increased irrigation and crop raising; however, the increase apparently is not great and cannot be determined from salinity plots.

Specific conductivity vs. discharge for the Milk River at Nashua and Harlem (Figure 12) shows no obvious trend in salinity. For a clear graphical presentation, only selected years typical of the streams records are shown in Figure 12. The Milk River has salinity problems, and the downstream increase in salinity between Harlem and Nashua is very apparent from Figure 12.

Salinity in the Musselshell River (discussed in detail in Section VI shows a sharp increase in the past eight years - probably due to increased irrigation activities.

Another approach to determining stream salinity trends is to examine water quality data from municipal water supplies that obtain their water from streams. Of the 221 municipal water supplies (location on map Appendix 1) listed by the Water Quality Bureau as of March 1973, a total of 41 communities have streams as the sole water source, and 15 have streams or a partial water source. Of the 56 communities that use streams only 12 are considered to be from streams that are or may be impacted by salinity. These are Chinook, Glasgow, Havre, and the Hill County Water District (from Fresno Reservoir) all from the Milk River; Fort Benton, Fort Peck and Culbertson from the Missouri River; Glendive, Miles City and Forsyth from the Yellowstone River; Cut Bank from Cut Bank Creek; Power from Muddy Creek and Chester from Tiber Reservoir (Marias River).

Water quality data from these municipal supplies was not sufficient to determine increased salinity in streams. Reasons for this were: parameters measured were limited; analysis did not cover long enough periods of time; samples analyzed were treated municipal water and did not represent raw stream water, and the streams had no flow measurements. Statistical analysis of data from the Water Quality Bureau and the USGS for the Milk River, Yellowstone and Missouri Rivers indicate no distinct increase in salinity. The municipal supply of Cut Bank comes from wells and Cut Bank Creek. One well was discontinued in 1965 because of a rapid increase in dissolved solids (see groundwater section, figure 25). A majority of the supply comes from Cut Bank Creek. This creek has shown an increase in total dissolved solids and has a saline creek feeding into it 12 miles above Cut Bank.

Public water supplies used to compile this list were based on communities that serve 25 or more persons. The new "Clean Drinking Water Act" (PL 93-523) defines public water supplies as any supply that furnishes 10 residential units or 25 or more persons. This will increase the number of public supplies in Montana from 221 to an estimated 1,500 to 2,000. Some of these supplies are taken from streams that are or may be impacted by salinity. Presently, insufficient data are available from these supplies to evaluate salinity trends.

VII. COUNTY SURFACE WATER AND SALINITY SURVEY

The Montana Department of State Lands in 1974 had the USDA County Committees for Rural Development compile a list of acreage affected by salinity damage. A total of 34 counties were listed with 120,814 irrigated acres affected by salinity and 140,485 dryland acres. To get a more comprehensive understanding of the problem, investigations were made to 32 of these counties. The purpose of these visits were to determine what type of damage was being caused and if it is related to saline seep from non-irrigated fields or salinity from irrigation of saline soils. Sampling sites were chosen to show what type of problems are caused by saline water and were located on what were considered saline areas. To determine where sampling would be appropriate, the local SCS (Soil Conservation Service) representative in each of the 32 counties was consulted.

If there was a problem, the SCS recommended several areas to sample and trips were made to these places. The landowners all were extremely cooperative and the problems they were having with saline seep were discussed. Often the problem was obvious, but collecting a water sample was difficult since much of the damage was being caused by sub-surface water, and no surface water was present. Other determining factors in choosing sites were water quality records for streams or well samples that showed salinity problems (See section VI for criteria), well data from USGS reports (same criteria), reports from individual farmers and ranchers on problems caused by saline water, and streams located downstream from saline areas.

The samples were all analyzed for common ions, nitrates and certain samples for metals (See Table 6 for Specific Parameters). The data from these samples should provide information on the constituents of saline water and their possible impact on ground and surface water. The following is a description by county of the type of samples collected and a general analysis of the saline problems involved.

Blaine County

Blaine County, located in northcentral Montana (Appendix H), has 10,000 acres of irrigated salinity* and 3,000 acres of saline seep. A majority of the irrigated salinity is present along the Milk River where naturally saline soils and seeping irrigation ditches are decreasing soil productivity. The Department of State Lands in cooperation with the Soil Conservation Service (SCS) in Chinook is researching the problems caused by irrigation salinity and possible solutions to the problem. The three samples collected in this county were taken from areas affected by irrigation salinity. Drainage ditches have been put at the edge of several fields to lower the water table and drain saline water. Samples were taken from two of these ditches and analysis indicated moderate conductivities of 1,200 umhos/cm @ 25°C and sodium adsorption ratio (SAR) values of 2.3 and sodium concentrations of 200 to 400 mg/l (milligrams

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* Acreage estimates presented in this report on saline affected lands were compiled by the Department of State Lands (1974).

Table 4

SALINE SEEP ACREAGE ESTIMATES* - 1974
RANKED BY SEVERITY OF PROBLEM

	COUNTY	ACRES AFFECTED
1.	Stillwater	23,000
2.	Chouteau	17,400
3.	Fergus	13,848
4.	Roosevelt	12,500
5.	Sheridan	10,000 - 12,000
6.	McCone	10,000
7.	Cascade	7,000
8.	Toole	6,000
9.	Daniels	5,400
10.	Liberty	4,600
11.	Judith Basin	3,500
12.	Richland	1,900 - 3,500
13.	Pondera	3,088
14.	Blaine	3,000
15.	Glacier	3,000
16.	Hill	2,000 - 2,500
17.	Meagher	2,300
18.	Madison	2,060
19.	Teton	1,600
20.	Phillips	1,500
21.	Big Horn	1,000
22.	Musselshell	924
23.	Valley	800
24.	Fallon	753
25.	Golden Valley	715
26.	Ravalli	701
27.	Yellowstone	600
28.	Lake	300
29.	Wibaux	300
30.	Prairie	250
31.	Carbon	200
32.	Dawson	106
33.	Lewis & Clark	100
34.	Custer	40
	TOTAL	140,485 - 142,585

* Compiled by Montana Department of State Lands from estimates supplied by County Committees for Rural Development

Table 5

IRRIGATION SALINITY ACREAGE ESTIMATES* - 1974
RANKED BY SEVERITY OF PROBLEM

	COUNTY	ACREAGE AFFECTED
1.	Madison	23,500
2.	Phillips	15,000
3.	Blaine	10,700
4.	Big Horn	9,000
5.	Carbon	8,350
6.	Lewis and Clark	6,420
7.	Ravalli	6,329
8.	Beaverhead	6,225
9.	Meagher	5,060
10.	Jefferson	4,600
11.	Powell	3,500
12.	Valley	3,500
13.	Sweet Grass	3,000
14.	Teton	2,789
15.	Pondera	2,059
16.	Gallatin	2,000
17.	Yellowstone	2,000
18.	Lake	1,500
19.	Stillwater	900
20.	Deer Lodge	700
21.	Park	669
22.	Golden Valley	572
23.	Judith Basin	500
24.	Sanders	500
25.	Musselshell	495
26.	Rosebud	350
27.	Treasure	200
28.	Richland	161
29.	Cascade	100
30.	Dawson	65
31.	Wheatland	30
32.	Daniels	20
33.	Prairie	20
	TOTAL	120,814

* Compiled by Montana Department of State Lands from estimates supplied by County Committees for Rural Development

Table 6

WATER QUALITY DATA FROM SALINE SEEPS AND OTHER SURFACE WATERS REFLECTING SALINE QUALITIES

Location	Date	Water Source	Flow cfs	Temp	Turb	pH	TSS	SC	TA	TH	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	COS	SAR	NO_3	PO_4	Fe	Mn	Cu	Cr	Zn	As	Hg	Pb	V	Se	Mo	Cd	B
BLAINE																																				
33N 20E 1188	8/26/74	Drain Ditch	—	15	—	9.1	—	1210	345	194	20	35	206	20	335	42	302	20	—	980	6.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
32N 21E 0600	8/26/74	Irrigation Return	—	15	—	8.4	—	1021	455	374	96	33	100	—	543	6	97	15	—	889	2.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33N 21E 338	8/26/74	Drain Ditch	—	—	—	7.7	—	3333	290	854	164	106	490	—	354	0	1469	70	—	2659	7.3	4.6	—	1.0	—	0.03	<.01	0.03	<.001	—	<.01	<.1	<.001	<.1	—	—
CARBON																																				
04S 22E 19AA	10/2/74	Canal	—	12	—	8.4	—	8360	4025	3145	600	400	950	—	4907	0	4813	36	—	11703	7.4	0.09	—	0.24	0.006	0.03	—	<.01	0.001	<.01	—	<.1	<.001	<.1	—	—
05S 23E 05	10/2/74	Seep	—	11	—	8.4	—	12960	410	4311	325	850	2125	—	476	12	7070	45	—	11403	14.1	—	—	0.56	0.18	0.18	—	<.01	0.002	—	<.01	<.1	<.001	<.1	—	—
05S 23R	10/2/74	Return Flow	1.0	11	—	8.5	—	2376	230	1126	245	125	170	—	256	12	9832	5	—	10658	2.2	13	—	0.09	0.09	0.01	<.01	<.01	<.001	—	<.01	<.1	<.001	<.1	—	—
CASCADE																																				
17N 01W 020	12/9/74	Pond	—	2	—	8.0	—	2734	212	1250	249	152	270	—	258	—	1474	49	—	2452	3.3	0.24	<.03	—	—	—	—	—	—	—	—	—	—	—	—	—
22N 02E 19AC	7/31/74	Seep Drain	0.004	20	—	4.3	—	8625	0	4750	421	899	780	—	—	—	6434	278	30	8842	4.9	—	—	0.47	16.0	0.08	0.04	4.2	<.001	—	<.01	<.1	0.018	<.1	—	—
CUSTER																																				
06N 52E 06CC	8/9/74	Sheep Creek	—	16	180	8.4	—	5010	628	256	36	40	1160	9.7	756	5	2066	3.3	1.2	4097	31.6	—	—	6.5	0.23	0.01	—	0.05	0.016	—	—	—	—	—	—	—
DANIELS																																				
34N 49E 2280	8/22/74	Pond	—	15.8	—	8.4	—	492	225	210	16	41	26	—	270	2	37	3.5	0.17	398.9	0.8	2.4	0.08	1.03	0.10	0.01	—	0.07	0.001	—	—	—	—	—	—	—
34N 49E 3C	8/26/74	Coulee	1.0	18	—	8.1	—	—	320	235	70	39	22	—	390	0	50	50	—	623.8	0.5	6.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
36N 49E 350A	8/26/74	Coulee	—	13	—	8.2	—	815	438	413	81	51	14	—	529	2	31	4.0	—	713.3	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
34N 50E 27BR	8/26/74	Seep	0.06	—	—	8.1	—	1455	285	584	120	69	62.5	6	348	0	99	255	—	963.5	1.1	4.4	—	—	0.06	0.01	—	0.05	<.001	—	0.01	<.1	0.002	<.1	—	—
36N 48E 28B0	8/26/74	Lake	—	18	—	10.0	—	—	5274	32	13	0	4700	—	2013	2172	4163	300	0.17	13361	359.2	6.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
FALLON																																				
10N 57E 35AA	8/21/74	Cabin Creek	—	—	—	7.9	—	980	183	108	20	19.0	320	—	223	0	576	97	—	1250	13.4	8.0	—	2.2	0.30	0.01	<.01	0.03	<.001	—	<.01	<.1	<.001	<.1	—	—
07N 60E 24CC	8/21/74	Hand Pump	—	13	—	7.5	—	6000	290	3324	409	559	513	—	354	0	3872	60	—	5780	3.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
07N 60E 26B0	8/21/74	Seep	—	14	—	6.9	—	—	132	4480	962	505	2730	—	161	0	8853	100	—	13315	17.5	4.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
07N 56E 04DA	8/21/74	Creek	—	19	—	8.5	—	4530	380	1214	370	70	637	10	342	24	10.2	30	—	1545	8.6	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
07N 60E 32C	8/20/74	Pond	—	32	—	8.3	—	2695	290	15280	537	3336	11750	—	329	12	44488	550	—	63054	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
04N 58E 17DR	7/24/74	Drain Pipe	—	20	—	8.0	—	8830	589	5340	549	846	930	—	718	0	6603	0.3	0.3	—	5.5	—	—	1.2	—	—	—	<.001	<.001	—	<.01	<.1	0.002	<.1	—	—
07N 60E 24CC	7/24/74	Well	—	8	—	7.6	—	5886	247	3490	387	596	500	—	301	0	0	43	0.05	—	—	0.2	—	0.49	0.60	0.01	<.01	<.001	<.001	—	<.01	<.1	0.003	<.1	—	—
FERGUS																																				
19N 12E 13RA	7/7/74	Arrow Creek	—	16	5	8	10	2194	238	956	189	118	180	—	271	0	1044	13.4	—	1834	2.5	—	0.05	0.27	0.04	0.006	—	—	0.005	—	—	—	—	—	<.001	—
20N 14E 19	11/6/74	Seep	0.0064	—	—	8.6	28	6450	534	610	83	98	1450	6.0	645	35	3100	0.5	—	5432	25.5	15	0.06	—	—	—	—	—	—	—	—	—	—	—	<.001	—
20N 14E 19	11/5/74	Arrow Creek	—	—	—	8.4	84	3283	292	1315	216	189	422	8.3	329	14	1775	39	—	3021	5.1	32	0.06	1.1	0.09	<.01	—	<.01	—	—	—	—	—	—	<.001	—
22N 14E 17	11/6/74	Arrow Creek	23	—	—	8.3	160	3640	283	1335	237	180	460	—	345	0	1905	39	—	3209	5.5	34	0.12	—	—	—	—	—	—	—	—	—	—	—	<.001	—
14N 12E 13RA	11/5/74	Arrow Creek	14	—	—	8.1	14	1973	240	773	179	79	190	—	300	0	833	16	—	1654	3.0	3.7	0.03	0.02	0.03	<.01	—	<.01	—	—	—	—	—	—	<.001	—
22N 16E 24RA	11/7/74	Dog Creek	0.09	2.0	—	8.0	8	2944	348	920	193	104	355	6.3	425	0	1227	34	—	2346	5.1	0.62	0.06	0.18	0.51	—	—	<.01	—	—	—	—	—	—	<.001	—
17N 15E 31DC	11/6/74	Sage Creek	6.1	5.0	—	7.9	34	2671	258	1124	208	148	225	7.0	315	6	1231	45	—	2151	2.9	0.89	0.03	0.44	0.01	<.01	—	<.01	—	—	—	—	—	—	<.001	—
17N 14E 32BA	11/6/74	Dry Wolf	—	3.4	—	8.2	12	5462	494	2210	209	410	730	7.8	630	0	3110	3.5	—	5107	6.8	35	0.09	0.32	0.02	<.01	—	<.01	—	—	—	—	—	—	—	—
17N 14E 32BA	10/16/74	Dry Wolf	0	13	—	8.4	2	9100	479	4060	305	801	1300	—	572	6	5900	179	—	9138	8.9	8.9	0.07	0.15	0.05	<.01	—	0.03	—	—	—	—	—	—	—	—
23N 15E 32CD	7/9/74	Arrow Creek @ Mouth	204	27	—	7.6	10100	3390	—	—	—	—	350	—	—	—	—	15	—	—	0	0.92	—	19.0	—	0.016	—	3.8	—	—	<.01	—	<.001	—	—	—
20N 14E 19	10/16/74	Arrow Creek	—	17.5	—	8.1	—	1910	231	736	171	75	233	—	940	0	940	18	—	1722	3.7	3.2	0.05	0.18	<.01	<.01	—	<.01	<.001	—	<.01	—	<.001	—	—	—
GOLDEN VALLEY																																				
06N 22E 280D	7/3/74	Big Coulee	—	17	R	8.1	12	4135	297	1272	48	281	640	—	363	0	2244	42	—	3615	7.8	0	0.03	<.01	<.01	<.01	—	<.01	—	—	—	—	—	—	<.001	—
06N 23E 150R	11/27/74	Painted Robe Crk	—	4	—	8.4	10	5270	396	1668	212	277	815	—	470	6	2800	92	—	4672	8.7	0.58	0.03	0.14	0.06	<.01	—	0.07	—	—	—	—	—	—	<.001	—
06N 22E 280D	8/7/74	Big Coulee	—	21	—	8.1	32	3658	288	1134	164	181	525	—	—	—	1974	2.0	0.26	3205	6.7	0.06	0.06	0.22	<.01	<.01	—	0.01	0.001	—	—	—	<.001	—	<.001	—
06N 20E 02AB	9/3/74	Careless Creek	48	11	—	8.4	48	1372	197	394	52	64	250	—	240	0	711	0.8	—	1318	5.5	0.02	0.12	0.38	0.69	—	—	—	—	—	—	—	—	—	—	—
06N 20E 02AB	10/11/74	Careless Creek	16	11	—	8.2	12	3140	309	905	143	133	430	—	377	0	1456	13.0	—	2552	6.2	0.19	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
GLACIER																																				
35N 06W 34RR	8/30/74	Seep	0.1	18	—	8.8	—	4110	610	440	56	74	895	—	730	12	1543	75	—	3373	18.5	53	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35N 06W 34BA	7/17/74	Seep	0.06	—	1	8.2	—	3989	0	0	—	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
HILL																																				
32N 11E 03BA	1/23/74	Sage Creek	—	2.0	68	8.3	10	4968	926	620	120	78	1010	—	1123	0	1413	245	0.87	4035	17.7	4.4	41	1.5	—	<.01	—	0.04	0.06	—	0.01	—	—	—	—	—
36N 13E 25C0	7/30/74	Reservoir	—	19	—	7.3	—	514	121	66	14.3	7.2	51	—	148	0	150	3.5	—	383	3.3	0.1	—	0.68	0.30	<.01	<.01	<.01	0.003	—	<.01	<.1	<.001	<.1	—	—
36N 13E 22AC	7/30/74	Reservoir	—	18	—	8.2	—	169	80	68	17.2	6.0	2.8	—	98	0	3.5	0.3	—	127.5	0.1	0.1	—	1.7	0.30	<.01	<.01	<.01	<.001	—	<.01	<.1	0.004	<.1	—	—
JEFFERSON																																				
01N 04W 10CR	10/22/74	Drain Ditch	2	4	—	—	—	1344	431	293	54	39	171	—	525	—	205	2.5	1.9	998	4.3	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
02N 04W 3300	10/22/74	Irrigation Ditch	—	8	—	7.5	—	782	243	243	86	21	55	—	296	0	122	30	0.40	612	1.4	0.09	—	—	—	—	—	—	—	—	—	—	—	—	—	—
LIBERTY																																				
35N 06E 36AC	8/30/74	Well	—	—	—	7.9	—	942	200	415	101	39	50	—	244	0	298	5	—	734	1.1	8.0	—	0.21	0.83	0.04	—	3.6	<.001	—	<.01	<.1	<.001	<.1	—	—
35N 04E 14C0	8/29/74	Canal	—	62	—	9.5	—	—	110	5680	429	2062	3200	—	0	60	14156	150	—	19143	18.5	1.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37N 06E 22RB	8/30/74	Seep	—	—	—	8.1	—	36000	1741	26245	—	6375	6375	—	2123	0	9573	250	—	24696	17.1	—	—	0.81	0.41	0.06	—	0.11	0.002	—	<.01	<.1	0.090	0.1	—	—
MADISON																																				
01S 05W 23AA	10/22/74	Ditch	—	7.0	—	8.7	—	1786	383	692	59	132	152	—	417	28	535	2.9	0.10	1326	2.5	0.34	—	1.4	0.07	0.02	—	—	—	—	<.01	<.1	—	<.1	—	—
McCONE																																				
26N 49E 22AA	8/26/74	Seep	—	18	—	8	—	4230	130	934	180	220	750	13	159	0	2073	25	—	3297	10.7	53	—	0.33	0.89	0.02	<.01	0.02	0.001	—	<.01	<.1	<.001	<.1	—	—
27N 50E 35A	10/22/74	Redwater River	2	3	47	8.8	178	3203	781	265	26	49	700	—	858	47	950	0.5	1.5	2647	18.7	0.04	0.03	2.6	0.48	<.01	—	0.05	—	—	—	—	—	—	<.001	—
27N 50E 35A0	7/10/74	Redwater River	—	29.5	37	8.9	—	2200	451	411	41	75	625	20	478	35	1232	38	—	2526	13.4	0.13	0.04	0.13	—	0.02	—	<.01	<.01	—	<.01	—	—	—	<.01	—
17N 46E 21B	10/22/74	Redwater River	40	4.0	—	8.7	116	8401	669	2050	68	457	1950	—	735	40	5450	0.3	0.21	8720	18.7	0.06	0.34	1.3	0.44	0.01	—	<.01	<.01	—	—	—	—	—	<.001	—
MUSSELSHELL																																				
07N 25E 07CC	2/12/74	Current Creek	Ice	1.0	64	7.7	—	8090	502	2628	534	315	1300	3.5	611	0	4100	47.5	3.0	7373	11.0	0.93	0.03	5.7	—	0.05	—	0.06	0.001	—	—	—	—	—	—	1.4
07N 25E 07CC	9/11/74	Current Creek	28	8.4	85	8.4	138	1192	224	422	83	52	112	4.5	268	2	430	2.5	0.29	955	2.4	0.15	0.03	2.6	—	0.01	—	—	—	—	—	—	—	—	—	—
PHILLIPS																																				
30N 31E 01AC	8/27/74	Lake Bowdoin	—	20	—	8.7	—	6700	760	724	98	149	1450	—	732	96	2703	230	—	5405	23.5	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
31N 31E 32CC	8/27/74	Bowdoin Inflow	—	15	—	8.3	—	630	165	176	29	25	59	—	189	6	117	9	—	434	1.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30N 31E 01CC	8/27/74	Dry Lake Outlet	—	20	—	9.4	—	8650	871	1060	52	226	1800	—	573	240	3822	245	—	6962	24.1	4.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
31N 32E 33BD	8/27/74	[illegible]on Canal	—	—	—	8.5	—	7030	570	768	[illegible]	157	187	—	622	36	2968	255	—	426[illegible]	2.9	0.58	0.91	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 6
(Continued)

Location	Date	Water Source	Flow cfs	Temp	Turb	pH	TSS	SC	TA	TH	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	CDS	SAR	NO_3	PO_4	Fe	Mn	Cu	Cr	Zn	As	Hg	Pb	V	Se	Mo	Cd	B
PETROLEUM																																				
12N 30E 34BD	8/6/74	North Willow Crk	—	25	75	7.9	127	8940	130	1655	311	214	2000	17	159	0	5443	83	0.95	8226	21.4	0.14	0.03	2.2	0.15	0.01	—	0.04	<.001	—	—	—	<.001	—	—	—
18N 26E 06CB	8/7/74	Yellowwater Creek	—	18	32	8.1	22	8820	464	3405	283	656	2700	14	566	0	8200	0.3	1.47	—	20.1	0.25	1.1	0.8	0.71	<.01	—	0.03	0.001	—	—	—	<.001	—	—	—
17N 26E 04CB	7/1/74	Yellowwater Creek	0.3	25	36	7.8	—	7850	294	2890	200	580	1297	9.0	358	0	5147	47	—	7641	10.5	1.3	0.19	1.5	0.58	0.01	—	0.05	0.002	—	—	—	<.001	—	<.001	—
28E 15N 34C	7/1/74	Box Elder Creek	0.2	26	8	8.4	7.0	3061	191	541	91	76	523	9.0	234	4	1370	18.5	—	2372	9.8	46	1.2	0.32	0.02	<.01	—	0.05	<.001	—	—	—	—	—	<.001	—
28E 15N 34C	8/8/74	Box Elder Creek	0	28	36	9.0	32	3682	313	276	32	48	770	10	350	16	1617	1.1	0.81	2844	20.2	0.18	0.09	0.33	0.02	0.01	—	0.03	<.001	—	—	—	—	—	<.001	—
14N 26E 12AD	7/1/74	McDonald Creek	11.3	24	31	8.0	33	2203	181	1004	199	123	156	6.0	221	0	1070	6.5	—	1838	2.1	56	0.60	1.2	0.36	<.01	—	0.02	<.001	—	—	—	—	—	<.001	—
14N 26E 12AD	8/8/74	McDonald Creek	8.2	19	37	8.2	57	2327	197	1040	222	118	110	6.0	240	0	1224	1.2	0.60	1922	1.5	—	0.03	0.78	0.18	0.01	—	0.03	<.001	—	—	—	—	—	<.001	—
PRAIRIE																																				
11N 54E 29CC	8/20/74	O'Fallon Creek	0.5	20	—	8.4	—	2990	350	180	72	0	565	—	403	22	1168	15	—	2235	18.3	4.4	—	0.49	0.08	0.02	—	0.02	<.001	—	<.01	<.1	0.004	<.1	—	—
12N 52E 03DA	4/25/74	O'Fallon Creek	28.8	22	—	8.3	—	2890	358	514	82	75	500	—	437	0	1177	18.4	—	2289	9.6	—	—	0.10	0.05	0.01	—	0.02	—	<.001	—	—	—	—	<.001	—
12N 52E 02B	7/11/74	O'Fallon Creek	—	—	45	8.6	76	1897	275	300	50	55	400	9.0	309	13	880	16.8	0.4	1733	9.3	—	—	1.6	0.05	<.01	—	<.01	—	—	—	—	—	—	—	—
12N 52E 02B	7/17/74	O'Fallon Creek	—	26	—	8.5	—	2067	305	363	58	53	380	—	353	10	847	11.4	0.37	1712	8.7	0.39	0.02	—	—	—	—	0.05	—	—	0.01	—	—	—	<.01	—
RICHLAND																																				
25N 58E 2600	8/23/74	Second Hay	0.1	17	—	8.6	—	9020	380	1608	48	361	2400	—	342	60	6100	30	—	9341	26.0	6.6	—	0.33	0.65	0.03	—	0.02	0.010	—	<.01	<.1	<.001	<.2	—	—
25N 57E 368B	8/24/74	Lone Tree	0	0	—	7.8	—	9125	100	4328	184	939	2225	—	122	0	6656	—	—	9127	8.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ROOSEVELT																																				
27N 51E 0788	8/23/74	Poplar River	—	20	—	8.8	—	1277	395	144	20	23	225	—	433	24	204	215	—	1144	8.2	4.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30N 56E 2100	8/24/74	Lost Creek	—	16	—	8.1	—	5910	540	4854	545	300	152	—	659	—	3995	60	—	6410	0.9	151	—	0.14	0.60	0.04	—	0.02	<.001	—	<.01	<.1	<.002	<.1	—	—
29N 56E 3088	8/24/74	Sheep Creek	0.1	16	—	7.8	—	2621	270	924	96	166	250	—	329	—	1123	220	—	2084	3.6	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28N 58E 27CD	8/24/74	Shotgun Creek	3	17	—	7.9	—	1485	582	284	28	52	281	—	720	—	390	10	—	—	—	7.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ROSEBUD																																				
06N 41E 03AC	4/18/74	Little Porcupine Crk	2.8	—	—	8.0	—	4802	167	1598	465	106	894	—	203	0	2238	349	2.7	3958	6.5	—	0.06	0.90	0.50	0.02	—	0.01	—	<.001	—	0.46	<.001	—	<.01	—
06N 40E 28AA	4/19/74	Smith Creek	0.17	15	—	8.5	—	2154	516	256	46	34	431	—	608	10	648	0	0.8	1778	11.7	—	0.03	0.20	<.01	0.01	—	0.01	—	<.001	—	—	—	—	<.001	0.22
07N 37E 26AC	4/19/74	Starved-to-Death Crk	0.01	12	—	7.6	—	2263	34	417	95	43	360	—	41	0	1124	4.0	0.46	1668	7.7	—	0.83	0.16	<.01	0.01	—	0.01	—	<.002	—	0.63	<.001	—	<.001	—
05N 38E 35CB	12/27/74	Reservation Creek	0.85	17.7	—	7.8	—	1945	357	525	96	69	278	—	436	0	745	12.6	0.34	1637	5.3	—	0.01	0.18	<.01	<.01	—	<.01	—	<.001	—	—	—	—	<.01	—
SHERIDAN																																				
34N 58E 33BC	8/25/74	Clear Lake	—	—	—	9.6	—	5160	128	4304	1683	0	1125	—	756	396	1728	45	—	5734	4.4	4.4	—	—	0.15	—	—	—	—	—	—	—	—	—	—	—
34N 52E 36AC	8/25/74	Seep	—	—	—	8.1	—	2025	270	680	58	130	105	—	329	0	551	20	—	1194	4.4	4.4	—	0.24	—	0.01	—	0.03	<.001	—	<.01	<.1	<.001	<.1	—	—
33N 58E 22DC	8/25/74	Brush Lake	—	—	—	9.4	—	6100	670	1121	449	0	388	—	464	174	0	60	—	1538	3.4	3.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
36N 58E 02BD	8/25/74	Pond	—	18	—	7.8	—	1795	520	624	96	93	450	—	0	0	1038	25	—	1942	62	62	—	61	14	0.17	—	0.33	<.001	—	<.01	<.2	0.001	<.1	—	—
STILLWATER																																				
02N 21E 24	10/2/74	Lake	—	12.5	—	8.8	—	37100	645	11504	650	2400	10100	—	567	108	31883	1610	—	47328	41.0	8.9	—	0.33	0.64	0.11	—	0.05	0.007	—	<.01	<.1	<.001	<.1	—	—
01N 21E 07CA	10/2/74	Pond	—	22	—	9.6	—	50800	240	25302	900	5600	23700	—	49	170	48545	3200	—	72123	37.5	9.3	—	3.8	0.02	0.15	—	0.07	0.035	—	<.01	<.1	0.002	<.1	—	—
01N 22E 15BA	7/22/74	Tapwater	—	25	—	8.5	—	3565	650	482	72	74	880	—	759	17	893	150	1.83	2846	17.4	—	—	0.07	0.11	0.02	<.01	0.02	<.001	—	<.01	<.2	0.009	<.1	—	—
03N 21E 180A	7/22/74	Hailstone	—	25	—	8.9	—	33400	510	27059	493	6283	14500	—	354	132	55169	869	1.0	77800	38.3	—	—	2.6	0.10	0.19	<.01	0.18	<.001	—	<.01	<.1	0.005	<.1	—	—
02N 22E 03CC	7/22/74	Pond	—	26	—	8.3	—	10300	340	4700	344	933	2210	—	415	0	8672	338	1.0	12913	14.0	0.09	—	0.62	0.22	0.50	<.01	0.04	<.001	—	<.01	<.1	0.005	<.1	—	—
01N 22E 15AD	7/22/74	Seep	—	25	—	7.9	—	4537	538	62	14	6.6	950	—	656	0	1567	232	0.66	4537	32.5	5.0	—	9.4	1.3	0.02	<.01	0.08	<.001	—	<.01	<.1	0.065	<.1	—	—
SWEET GRASS																																				
03N 15E 100	8/16/74	Stock Pond	—	18.8	—	8.3	—	307	137	121	33	9	17	—	160	4	31	2.3	0.14	256	0.7	0.05	—	2.3	0.02	0.01	—	0.03	<.001	—	<.01	<.1	<.001	<.1	—	—
03N 14E 02A	7/16/74	Gleston Reservoir	—	—	—	8.2	—	—	—	—	27	9.3	18.2	—	132	0	39	5.0	—	213	—	0.04	0.12	0.70	0.04	0.02	—	0.18	<.001	—	<.01	<.1	<.001	<.1	—	—
03N 13E 10D	8/16/74	Canal	—	—	—	—	—	—	—	—	36	12.1	53	—	206	8	79	5.8	0.30	400	1.9	0.01	—	0.11	0.01	<.01	—	—	<.001	—	<.01	<.1	<.001	<.2	—	—
TETON																																				
23N 04W 16	4/23/74	Creek	0.6	24	—	8.4	70	11100	606	4966	340	1000	1875	10	708	16	7693	367	0.66	11978	11.6	10	0.29	—	—	—	—	—	—	—	—	—	—	—	—	—
24N 04W 160	4/23/74	Creek	0.2	17	—	8.2	1	4590	278	2600	555	295	365	12	339	0	3020	163	0.44	1603	3.1	0.12	0.03	—	—	—	—	—	—	—	—	—	—	—	—	—
23N 04W 090	4/23/74	Creek	0.2	18	—	8.2	4	7440	330	3549	465	580	840	21	403	0	4871	45	0.26	7227	6.1	1.3	0.68	—	—	—	—	—	—	—	—	—	—	—	—	—
23N 04W 020	4/24/74	Creek	0.2	9	—	8.2	32	9950	627	3116	275	590	1838	—	765	0	5727	331	0.82	—	14.3	0.28	0.21	0.38	—	0.14	—	0.01	<.01	—	—	—	—	—	—	—
23N 04W 160	10/01/74	Creek	1.0	5	—	8.0	—	4850	315	3146	650	370	300	—	384	0	3324	15.0	—	5052	2.3	0.89	—	—	—	—	—	—	—	—	—	—	—	—	<.01	—
23N 04W 04BB	10/01/74	Trib to Priest Lake	0.4	9	—	7.8	—	36000	280	2134	650	124	100	—	342	0	1950	0	—	3179	0.9	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23N 01E 21AA	10/01/74	Lone Creek	—	9	—	3.6	—	40000	0	8335	700	1600	2600	—	—	0	74	225	—	5203	12.4	4.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24N 03W 210	10/01/74	Seep	0.1	—	—	7.8	—	29300	1091	19649	120	4700	7700	—	1330	0	34122	495	0.23	50770	23.4	2304	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23N 01E 06DC	10/01/74	Coulee	0.1	—	—	8.4	—	38000	760	10942	425	2400	12900	—	903	12	32583	5750	—	55381	53.7	408	—	5.2	0.60	0.08	0.06	<.001	—	—	<.01	<.1	0.82	0.3	—	—
TOOLE																																				
29N 01E 10AC	8/30/74	Pond	—	15.5	—	8.7	—	—	3167	95358	481	22871	15375	—	2653	594	117619	1600	—	161193	21.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37N 01E 19CB	8/30/74	Seep	—	27	—	8.6	—	—	1251	38399	2300	8539	7700	—	817	348	52906	2550	—	73160	71.1	1019	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37N 01W 17BA	8/25/74	Pond	—	—	—	10.3	—	4040	1131	870	10.4	205	904	—	232	364	1641	25	—	3578	13.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33N 04W 02BA	8/30/74	Pond	—	16	—	9.0	—	—	6	1841	160	31	4040	10.3	—	—	6093	1885	—	12672	41.3	80	—	0.41	0.39	0.05	—	0.02	0.028	—	<.01	<.1	<.001	<.1	—	—
31N 02W 34BB	4/20/74	Coulee	0.3	14	2	8.3	—	22100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35N 02W 03A	8/8/74	Reservoir	—	22	8.3	9.2	22	3218	226	953	184	220	415	60	204	25	165	56	—	428	5.9	0.04	0.28	1.6	0.08	0.02	—	0.05	0.02	—	0.01	—	—	—	—	—
35N 02W 09B	8/8/74	Irrigation Runoff	—	24.5	1.7	7.9	2	6540	0	—	—	—	2600	45	—	—	40	—	—	1701	0.0	9.0	1.5	—	—	—	—	0.04	—	—	—	—	—	—	—	—
35N 02W 09CA	8/8/74	Reservoir	—	13	7.5	8.2	6	—	331	6525	455	2309	11	52	404	0	13900	595	—	16744	0.0	18.0	0.81	2.0	0.81	0.03	—	0.06	0.022	—	0.10	—	—	—	—	—
35N 02W 09CA	8/8/74	Reservoir	—	—	—	8.0	62	—	202	4670	261	976	1800	53	246	0	10950	540	—	14844	11.5	18.0	0.40	0.63	0.05	0.04	—	0.05	0.021	—	0.08	—	—	—	—	—
31N 02W 34BB	10/1/74	Nilger Coulee	1.0	11	—	8.5	—	—	530	24442	1050	5300	1300	—	573	36	17896	70	—	26619	3.6	594	—	0.85	0.18	0.07	—	—	<.001	—	<.01	<.1	1.3	0.2	—	—
TREASURE																																				
06N 37E 18AB	2/9/74	Sarpy Creek	3.7	0	—	8.1	—	1793	349	440	74	62	238	—	426	0	582	7.2	—	1390	4.9	0.78	0.25	0.60	—	<.01	—	<.01	—	—	<.01	—	—	—	—	—
06N 37E 18AB	6/11/74	Sarpy Creek	30	16.7	81	8.7	148	2205	311	630	107	88	325	—	329	25	962	12.5	—	1849	5.6	0.06	0.04	3.0	0.17	<.01	0.01	0.02	0.002	—	—	0.04	<.001	—	—	0.33
06N 37E 300D	7/31/74	Sarpy Creek	—	—	—	8.5	12	4300	604	885	82	165	770	—	704	16	1841	0.2	—	3578	12.3	0.20	0.09	0.25	0.20	<.01	0.04	—	0.002	—	—	0.53	<.001	—	<.001	0.51
06N 37E 19BA	10/22/74	Sarpy Creek	0.2	8.2	7.9	8.2	—	3130	470	770	122	113	515	—	573	0	2345	17.0	—	2689	8.1	3.3	0.03	0.65	0.69	0.01	—	<.01	—	—	—	—	—	—	<.001	—
06N 37E 18AB	4/17/74	Sarpy Creek	3.2	10.5	—	8.3	14	2656	456	758	91	229	385	—	556	0	1096	11.8	—	2269	6.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
WHEATLAND																																				
06N 17E 15AA	10/16/74	Mud Creek	—	—	—	7.8	—	5850	—	—	—	—	—	—	—	—	3201	166	—	—	—	—	—	0.60	0.08	0.03	—	0.12	0.004	—	<.01	<.1	<.001	<.1	—	—
08N 15E 18CC	10/16/74	Creek	—	—	—	8.1	—	2450	—	—	—	—	—	—	—	—	1076	39	—	—	—	—	—	0.07	<.01	0.02	—	0.04	<.001	—	<.01	<.1	0.005	<.1	—	—
08N 18E	10/16/74	Creek	—	—	—	7.8	—	1550	—	—	—	—	—	—	—	—	650	11.4	—	—	—	—	—	<.01	<.01	<.01	—	0.03	<.001	—	<.01	<.1	0.004	<.2	—	—
08N 15E 16CC	10/16/74	Seep (?)	—	—	—	7.9	—	3930	—	—	—	—	—	—	—	—	2200	22.4	—	—	—	—	—	0.07	0.08	0.02	—	0.07	<.001	—	<.01	<.1	0.001	<.1	—	—
08N 15E 23AD	8/7/74	Antelope Creek	1	21	2	8.4	—	2170	197	800	164	95	255	—	235	2	1058	11.4	0.36	1804	3.6	0.23	0.03	0.20	0.02	<.01	—	<.01	0.001	—	<.01	<.1	—	—	—	—

Table 6
(Continued)

Location	Date	Water Source	Flow cfs	Temp	Turb	pH	TSS	SC	TA	*TH	Ca	Mg	Na	K	HCO$_3$	CO$_3$	SO$_4$	Cl	F	CDS	SAR	NO$_3$	PO$_4$	Fe	Mn	Cu	Cr	Zn	As	Hg	PB	V	Se	Mo	Cd	B
VALLEY																																				
33N 42E 1300	8/27/74	Seep	———	15	——	8.1	———	1669	665	550	64	95	378	——	811	0	252	10	——	1609.9	7.0	8.9	——	0.28	0.96	<.01	——	0.06	0.002	——	<.01	<.1	<.001	<.1	——	——
30N 42E 14	9/12/74	Newby Pond	———	——	——	8.4	———	2807	490	940	144	141	360	——	590	4	1042	87	0.95	2371	5.1	0.15	——	2.6	0.12	0.03	——	0.01	<.001	——	<.01	<.1	0.001	<.1	——	——
35N 43F 14	9/12/74	Pond	———	——	——	9.5	———	903	319	265	20	52	120	8.2	26.7	80	195	4	1.00	727	3.2	0.09	——	0.43	0.06	0.03	——	0.01	0.004	——	<.01	<.1	0.001	<.1	——	——
33N 38E 26	9/12/74	Pond	———	——	——	7.2	———	292	50	63	11.8	8.1	22	——	60	0	62	1.9	0.17	166	1.2	0.05	——	0.30	0.30	0.02	——	0.02	0.002	——	<.01	<.1	<.001	<.1	——	——
27N 45E 11	9/12/74	Pond	———	——	——	7.7	———	298	144	138	33	13.6	3.0	——	176	0	2.6	2.0	0.14	230	0.1	0.02	——	1.6	0.55	0.01	——	0.02	0.002	——	<.01	<.1	<.001	<.1	——	——
27N 40E 06AA	8/27/74	Irrigation Flow	———	12	——	7.9	———	1514	360	480	108	51.0	155	——	439	0	344	50	——	1147	3.1	75	——	——	——	——	——	——	——	——	——	——	——	——	——	——
34N 39E 28	9/12/74	Pond	———	——	——	7.3	———	139	60	47	12.8	3.7	8.2	——	73	0	6.5	1.1	0.10	106	0.5	0.07	——	1.5	0.31	0.02	——	0.01	0.001	——	<.01	<.1	<.001	<.1	——	——
27N 40E 06AD	8/27/74	Irrigation Flow	———	18	——	8.0	———	863	120	143	36	13.0	80	12	146	0	200	7.0	——	494	2.9	7.5	——	——	——	——	——	——	——	——	——	——	——	——	——	——
30N 42E 14DD	8/27/74	Tomato Can Creek	———	——	——	9.0	———	7400	390	1384	140	248	1360	26	354	80	3620	215	——	8028	18.0	4.4	——	——	——	——	——	——	——	——	——	——	——	——	——	——
26N 40E 0380	7/27/74	Galloping Coulee	———	20.5	——	7.8	———	409	182	178	44	16.5	5.8	——	222	0	30	0.8	0.12	319.2	0.2	———	——	0.4	0.17	0.02	——	0.03	0.005	——	<.01	<.1	0.004	<.1	——	——
27N 40E 30AA	7/27/74	Pond	———	18.3	——	7.2	———	243	107	92	24	7.9	3.0	——	———	0	———	———	——	———	———	———	——	——	——	——	——	0.02	0.004	——	<.01	<.1	0.001	<.1	——	——
WIBAUX																																				
13N 60E 14AD	8/21/74	Seep	———	22	——	7.5	———	1828	165	984	212	110	17.5	33.5	201	0	875	10.0	——	———	0.2	8.0	——	——	——	——	——	——	——	——	——	——	——	——	——	——
14N 60E 12	7/10/74	Pond	———	0	——	7.3	———	4190	596	3400	687	409	170	——	727	0	3229	12.8	——	5234	1.3	0	0.07	——	——	——	——	——	——	——	——	——	——	——	——	——
13N 61E 31C	7/10/74	Pond	———	0	——	7.5	———	3390	688	2660	503	341	170	——	839	0	2275	0	——	4129	1.4	0	0.08	——	——	——	——	——	——	——	——	——	——	——	——	——
YELLOWSTONE																																				
03N 23E 01	10/2/74	Pond	———	12.0	——	8.4	———	13992	130	4059	595	825	2900	0	134	12	5100	2800	——	4597	19.8	0.04	——	0.30	0.28	0.02	——	0.01	0.006	——	<.01	<.1	0.004	0.2	——	——

All results expressed in mg/l unless otherwise stated.
All metals are total recoverable unless otherwise designated.

Reference: Montana Water Quality Bureau.

per liter). Analysis of metals indicated moderate to low metal concentrations. In another irrigation return ditch the water sampled had a moderate conductivity, 2.3 SAR value, and sodium concentration of 100 mg/1 (Table 6).

Carbon County

Affected acreage in Carbon County is estimated at 200 dryland acres and 8,350 irrigated acres. Water samples were collected at a return flow to the Clarks Fork River, feeder canal, and pond seepage. These waters are extremely high in dissolved solids and constitute a threat to livestock and crops (Table 2 and Table 6). Sodium hazard ranges from low to medium, and the salinity hazard from high to very high (Figures 7 and 8). The dominant problem is a result of soil leachate. This leachate is high in sodium salts which results in undesirable water quality. Continued undisciplined water use will magnify these water quality problems.

Heavy metal concentrations (Table 6) were not observed to be problematical. However, the nitrate concentration (Table 6) in the irrigation return flow is detrimental to the Clarks Fork River. High nitrate concentrations contribute to stream enrichment (eutrophication).

Comparison of 1954 and 1974 aerial photos shows that this seep problem is growing. Unless careful water management practices are employed, this problem will magnify and manifest itself in very poor water quality (essentially true for most of the state).

Cascade County

Cascade County, located in the northcentral part of the state, has reported 100 acres of irrigation salinity and 7,000 acres of dryland saline seep. Much of this county is underlain by the Colorado Shale of Cretaceous geological age and has significant areas covered with glacial deposits. The terrain is mostly rolling hills with rock outcrops and buttes. One sample was collected from a saline pond which had a conductance of 2,734 umhos/cm @ 25°C and SAR value of 3.3 (Table 6). Several other sites were visited, but samples could not be collected. Shamrock Lake, a dry lake of about 10 acres northeast of Ulm, was crusted with salt. North of Great Falls, salt traces could be seen in coulees, but there was no flowing water. Most of the area north of Great Falls is in dryland farming. Another sample, collected from tile draining a saline seep area, had a conductance of 8,625. This water also had one of the higher selenium concentrations sampled (0.018 mg/1).

Custer County

Custer County, located in southeastern Montana, has 40 acres of saline seep. County SCS personnel felt there was no problem with saline seep or irrigation salinity; however, a sample collected at Sheep Creek near Mizpah showed saline waters. Sheep Creek had a conductivity of 5,010 and a SAR value of 31.6 and significant amount of iron, zinc, copper and manganese. Further studies of the creeks in the county are needed to determine the extent of saline problems.

Daniels County

Daniels County, located in the northeast corner, has saline seep on 5,400 acres and irrigation salinity on about 20 acres. Much of this county is underlain by the Fort Union Formation and is covered by glacial ground moraine deposits. Salinity problems in Daniels County occur naturally and from man-made disturbances. A natural alkali pond north of Scobey was sampled and had a conductivity greater than 10,000 and a SAR value of 359. This pond also had high concentrations of sodium, sulfate, and chloride (Table 6). Saline seep in this county can be found along both sides of the Flaxville Bench which trends north to south. This land is used for grazing and dryland farming. Samples were taken from the east and west sides of the Bench to determine water salinity. All samples had moderate conductivities and low SAR values. There were no abnormal metal concentrations (Table 6).

The Soil Conservation District at Scobey purchased a specific conductivity meter and will be working with the farmers to pinpoint sources of saline waters. Another area which will shortly be studied is the Poplar River. After spring high flow, the Poplar River is not suitable for irrigation according to the SCS. Many streams in this county with low summer flow become saline and can be damaging to crops. There are plans by the Canadian government to use the East Fork of the Poplar River for energy development. What effect this will have on the Poplar River will be studied this summer.

Fallon County

Fallon County, in southeastern Montana, has a reported 250 acres of saline seep affected land. Water quality data for this county has been collected by the Environmental Quality Council, Lower Yellowstone Basin Study (Karp, 1975), old water quality records, and samples collected for this saline seep study. Water samples were collected from streams, springs, ponds, and wells. Salinity problems in this county have resulted from dryland agriculture, discharge of brine from oil wells, and natural conditions.

The land around Baker is rolling hills with rock outcrops. This type of terrain lends itself to saline seep and loss of soil productivity. Two farms were visited; both had extensive seep problems which are spreading and destroying productive farmland. The seeps can be seen at the bottom of slopes and are outlined by a lack of vegetation, salt crusts, or large patches of fireweed (Kochia). One sample was taken from a formerly usable well. The analysis of this sample had a conductance of 5,000, high sulfates (4,000 mg/l), and sodium. This sample also contained considerable metals including iron (49 mg/l), zinc (15 mg/l), and trace amounts of copper, manganese, and selenium (Table 6). A sample taken two miles northwest of this site from an abandoned spring was found to be unfit for livestock usage with 8,853 mg/l sulfate, 2,730 mg/l sodium, and 100 mg/l chloride. A small pond southeast of Baker originally sampled in 1962 was resampled to see if further water quality deterioration had occurred. Thus far, the historical analysis has not been located.

Fergus County

Fergus County is located in the central part of Montana and is Montana's ninth largest county. Of the total area (4,253 square miles) only nine square miles are water surface--most of which is the Missouri River. Fergus County ranks third in saline seep acreage with 13,848 affected acres. No salinity problems due to irrigation have been reported. In this inventory, ten sampling locations were utilized, and a complete survey of the Arrow Creek drainage was conducted. This unique drainage gradually deteriorates to a point where water is no longer suitable for most uses. The natural terrain and adjacent dryland farming practices contribute to water quality deterioration. The constituents of importance are: nitrate, dissolved solids, zinc, and sodium (Table 6). A small spring flowing into Arrow Creek (Table 6, 20N14E19) is a typical saline seep spring. (The adjacent land usage is dryland farming). These spring waters have a high sodium and salinity hazard. Sage Creek and Dog Creek exhibit moderate salinity. Due to dissolved minerals (Table 6), usage of these waters for most purposes would be unfeasible. Dry Wolf Creek originates as relatively good quality water; however, as it flows through dryland farm areas, it increases in dissolved solids, nitrates and sodium adsorption ratio (SAR) (Table 6).

Zinc was observed (mouth of Arrow Creek) to be the only metal that would be harmful to aquatic life. A concentration of 3.8 mg/l has proven toxicity (Water Quality Criteria, 1973). In the presence of copper and cadmium the toxicity of this element will increase (known as synergism).

Nitrate concentrations conducive to stream enrichment (Table 6) were also observed. Whether these concentrations are a result of saline seep or fertilizers is yet to be determined. Acceptable use of these waters may be determined by comparing Tables 2 and 3 versus Table 6.

Fergus County has limited surface waters and special efforts are needed to protect stream water quality. A more thorough discussion of area waters is presented in the Middle Missouri Basin Inventory (Kaiser, 1975).

Golden Valley County

Golden Valley County, located in southcentral Montana, is one of Montana's smaller counties (1,111 square miles) and its principal source of water is the Musselshell River, which is fed by numerous small streams. Saline affected acreage is estimated at 715 dryland and 572 irrigated.

Small streams and their water quality appears related to the natural terrain and alkali soils. Adjacent dryland farm operations may be contributing its share of salinity. The acreage affected by irrigation is largely due to leaching of salts. All the surveyed streams had measured SAR values beyond recommended limits and these streams exhibited abnormal dissolved solids, conductance, sulfate, sodium, and boron concentrations. No metals were observed at toxic concentrations.

The greatest water quality problem encountered in this county appears to be suspended sediment. This sediment partially originates from Careless Creek and Deadman's Basin. Whether this sediment originates from areas devoid of vegetation or from excess irrigation return flows is yet to be determined.

Saline problems encountered in this area are fairly diluted by waters from Martinsdale and Deadman's Reservoirs. These reservoirs are utilized for maintaining the river's flow. During low flow periods, chemical constituents are found in this greatest concentration; however, during these periods, irrigation usage is minimal. Dilution by spring runoff during the irrigation season undoubtedly keeps crop loss at minimum levels. The only liability herein is the continued salt accrual, which accrues in the soil and water.

A more complete evaluation of salinity problems is discussed by Kaiser (1975) in a Water Quality Inventory of the Musselshell Basin.

Glacier County

Glacier County is located in the extreme northern part of Montana and has an area of 3,006 square miles of which only 32 square miles is water surface. The majority of this water is contained in three lakes. This county has a reported 3,000 dryland acres and 572 irrigated acres as affected by saline seep. Much of Glacier County is covered by glacial till and soils are variable and soil maps generally do not indicate specific patterns. The water sampled area was near soils of Cut Bank Loam, with subsurface geology of Colorado Shale. This topography coupled with dryland farming is conducive to saline seep.

Salinity is affecting water quality in Cut Bank Creek (Garvin, 1974). The waters from seeps adjacent to Cut Bank Creek are high in sodium, nitrate, dissolved solids, and sulfates (Table 6). Beneficial use of these waters is restricted by their quality. These seeps would be classified as having a very high salinity hazard and a high sodium hazard (Figure 7 and 8). These waters would be marginally satisfactory for livestock but unsatisfactory for irrigation purposes.

Hill County

Hill County, located in the extreme northern part of Montana, covers 2,946 square miles of which 20 square miles is surface waters. The Milk River is the county's major waterway. The Milk River Basin is more thoroughly described by Bloom (1974).

The area's topography was influenced by continental glaciation. The dominant topographic feature is the Bearpaw Mountains and the geology is dominated by the Judith River and Claggett Formations. Soil descriptions are scant, but the soils are thought to be considered suitable for some irrigation. Dryland acres affected by saline seep are estimated at 2,500, with no acreage lost to irrigation.

Three sites were sampled for saline seep related waters. Sage Creek, near Gildford (Table 6), has the least desirable waters. These waters contained high concentrations of sodium, sulfate, and phosphate. Phosphate is not typical of saline seep and investigations to locate this nutrient source should be conducted. The SAR value and dissolved solids concentration shows (Tables 2, 3 and 6) these waters to be unfit for irrigation and marginal for livestock. Specific conductance and sodium concentration show these waters have a very high salinity hazard and a high sodium hazard (Figures 7 and 8).

Jefferson County

Jefferson County is located in the southwest portion of Montana. This county's topography is mostly mountainous and generally is not conducive to typical saline seep problems. No dryland seeps were reported; however, 4,600 acres of irrigated land are affected by salinity.

Sampling was conducted at a drain ditch and an irrigation ditch. Adverse concentrations of metals were not present but these waters did contain enough sodium (Table 6) to warrant careful water management practices. SAR indicates drain waters are approaching marginal irrigation usage.

The soils involved are alluvial, and it appears the problem in Jefferson County is related to poor water management practices. Continued poor water management will eventually lead to degradation of high quality waters. Both waters sampled would be classified as high salinity hazard and low sodium hazard (Figures 7 and 8).

Judith Basin County

Judith Basin is centrally located between the Missouri and Musselshell River basins. The county has an area of 1,800 square miles and has a varied topography. The topography is characterized by mountains and plains. Soils have been briefly described, and a water resources survey of Judith Basin (1963) lists local areas as having alkalinity or salinity problems. This report indicated deep drainage would correct these saline conditions. However, after 12 years the saline problem is increasing. Currently, Judith Basin lists 3,500 acres dryland and 500 irrigated affected acres.

Several streams originating in this county do not manifest saline qualities until they reach Fergus County. These streams may typify the effects of dryland farming. The waters originate as high quality with low salt concentrations; they then flow through an intense dryland farm area which causes increases in salt concentrations (See Fergus County Section).

Arrow Creek, near Stanford (Table 6) contains fair quality water; however, downstream the water becomes degraded. The downstream degradation is the result of saline seeps and natural erosion.

Liberty County

Liberty County, located in northcentral Montana, has an area of 1,439 square miles and 20 square miles of surface water most of which is in the Tiber Reservoir. This reservoir is located on the county's major waterway--the Marias River.

The topography consists of prairie and gently rolling hills. The geology is dominated by glacial till, Eagle Sandstone, and the Claggett and Telegraph Creek Formations. These formations together with existing soil types are conducive to saline seep development. Saline seep has affected 4,600 dryland acres in Liberty County making this county 10th in affected acreage.

Adjacent areas to sample sites are dryland farming. Due to saline seep, some farming was discontinued. The water samples were taken from seep, wells and a canal. The well water (groundwater section) was of good quality. Due to its proximity to seep affected lands, this well may prove to be a valuable monitoring site. The waters from the seep (flows to Laird Creek) and canal are typical saline waters with high concentrations of sulfates and magnesium that make these waters unpalatable and good laxatives (Table 6). High concentrations of dissolved solids make these waters unfit for irrigation as well as livestock (Tables 2, 3 and 6). The seep and canal waters are very high in salinity and sodium hazard. Except for zinc (3.6 mg/l), concentrations of metals were not unusual.

Madison County

Madison County is located in southwestern Montana and has a total area of 3,541 square miles of which 11 square miles are surface water. The topography is dominated by the Madison Mountain Range. Saline problems have affected a reported 2,060 dryland and 23,000 irrigated acres. The land affected consists of alluvial deposits ranging in thickness from a few feet to over 100 feet.

Generally, the county's soils and geological features do not lend themselves to development of typical saline seeps. The county's salinity problems are associated with irrigation.

The single water sample collected from Madison County was taken from an irrigation canal. The waters are basically good quality (Table 6), but they show typical irrigation salt accrual. Sampled waters have a high salinity hazard and a low sodium hazard (Figures 7 and 8). Table 3 indicates this water should be used with careful management practices.

McCone County

McCone County in eastern Montana has a surface area of 2,652 square miles of which 58 square miles are water surface area (mostly the Missouri River and a portion of Fort Peck Reservoir). The Redwater River is the county's other major waterway. The topography varies from rolling hills to steeply eroded canyons. The area geology is dominated by the Fort Union and Lebo Formations. Soils of McCone County are composed of glacial till, alluvium, and other parent geological materials.

Area soils such as the Cherry Association and Marias-Vanda Association contribute to the saline seep problem. This county has 10,000 to 12,000 saline affected acres.

Water sampling was conducted on the Redwater River and at one saline seep. Waters sampled are of the sodium sulfate type with dissolved solids and high SAR values that make these waters unsatisfactory for irrigation purposes (Tables 2 and 6) At low flow conditions, the Redwater River is unfit for poultry and lactating animals and their young (Table 2). Metals were not observed to be a problem. A value of 53 mg/l of nitrate was measured in water from this seep.

The major difficulty in this county is to discern whether the dryland farming is having an effect on the Redwater River, or if natural saline soils and geological formations are contributing to the dissolved solids concentration. Current agriculture practices will continue to increase the river's salt load. Further work is required to differentiate natural and man-induced salinity.

A proposed coal gasification plant for McCone County will undoubtedly accelerate the spread of saline seep. A current proposal plans to use excess plant water for irrigation, with return flows to the Redwater River. As these heavy soils are characterized by high pH and sodium values, it is doubtful that leaching will benefit the area's streams.

Musselshell County

Musselshell County, located in central Montana, has an area of 2,903 square miles. Currant Creek was the only stream sampled having saline tendencies; this stream is discussed in the Golden Valley section. Saline affected acreage is placed at 924 dryland and 494 irrigated acres.

Phillips County

Phillips County, located in northcentral Montana, is the state's second largest county with a total area of 5,287 square miles including 59 square miles of surface waters. Topography varies from steep slopes of the Little Rocky Mountains to rolling hills. The major waterway is the Milk River. Estimated salinity affected acreage is 1,500 dryland and 15,000 irrigated.

Subsurface geology consists of shales and sandstone specifically the Bearpaw Shale, Judith River Formation and Claggett Formation. These formations are exposed in various sections of the county. Soils in the river plain are dominantly composed of alluvium. Havre Loam and Scobey Clay Loam are found in this county and are characterized by poor drainage and their alkali content. These soils and geological characteristics are conducive to formation of saline seeps.

Figure 17 Accrual of Sodium During Summer Months at Selected Stations in the Musselshell River.

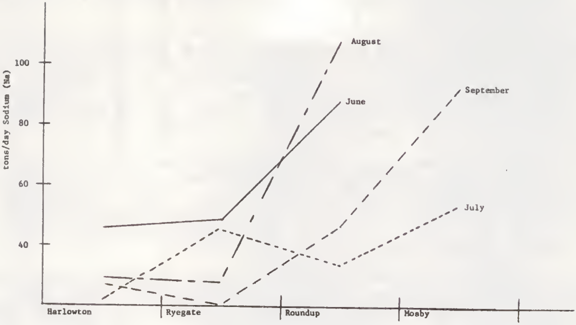


Figure 18 Suspended Sediment at Selected Stations on the Musselshell River.

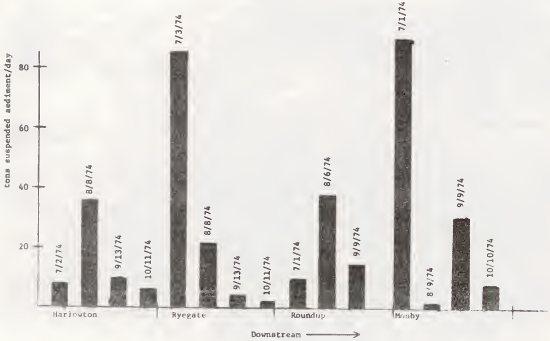


Figure 19 Sodium Adsorption Depicting Downstream Increases

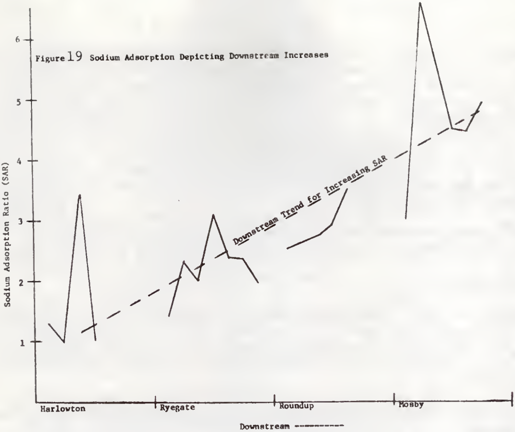
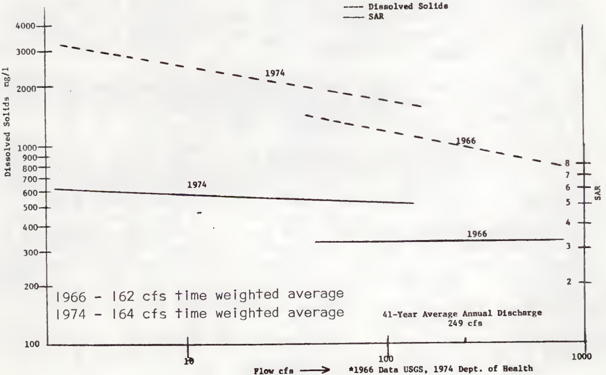


Figure 20 Depicting Changes in SAR* and Dissolved Solids in Musselshell River at Mosby.



1966 - 162 cfs time weighted average
1974 - 164 cfs time weighted average

41-Year Average Annual Discharge
249 cfs

*1966 Data USGS, 1974 Dept. of Health

Sampling was done near Lake Bowdoin, a lake that is considered alkali. Many of the saline areas present in the county are a result of irrigation seepage. Only one water sample indicated waters of good quality. This sample was taken at Lake Bowdoin's inflow (Table 6). Three other sites show high concentrations of dissolved solids (Table 6), sulfates, chlorides, sodium, and nitrate. These waters would not be suited for irrigation unless crops were tolerant and careful management practices were utilized. These waters also are unsuitable for lactating animals and poultry. Choride concentrations are unusually high and SAR values of 23.5 and 24.1 were among the highest SAR's recorded.

Saline waters may be affecting the water quality of Beaver Creek. Further investigation is needed to define impacts on other state waters.

Petroleum County

Petroleum County, located in central Montana and bounded on the east by the Musselshell River, has a surface area of 1,672 square miles, including 22 square miles of surface water. The topography consists of rolling hills and flat plains. This county has reported no salinity damaged acreage.

Geological formations found in Petroleum County are Hell Creek, Fox Hills, Bearpaw, Judith River, Claggett, Eagle, Colorado Shale, and Kootenai. Soils are basically clay loams and the alkali containing Marias clay loam. The proximity of marine shales, e.g., Colorado Shale, to adjacent streams contribute to the waters' salinity. To discern if area water quality changes are due to geologic formations, dryland farming, or overgrazing would require further investigation.

Streams depicting saline qualities are Box Elder, North Willow, Yellowwater, McDonald and Flatwillow Creeks and the Musselshell River (Table 6). The latter two streams depict saline qualities only during low flows. The Musselshell River (near Mosby) has saline qualities during irrigation season. Figures 17,18,19, & 20 show downstream water quality changes on the Musselshell River. Many of these quality changes are attributed to irrigation caused leaching, evapotranspiration, and some natural dissolution of salts.

The saline qualities of smaller streams may be attributed to natural agents; however, these saline tendencies may be aggravated or increased by dryland farming, overgrazing, and irrigation.

Of the aforementioned streams, Box Elder, North Willow and Yellowwater had the greatest sodium concentrations and the highest SAR values (Table 6). Due to dissolved solids, North Willow and Yellowwater Creeks would be unsatisfactory irrigation waters. During low summer flows, their use as livestock water would be limited (Tables 2 and 6). Nitrate concentrations of 46 and 56 mg/l were recorded in Box Elder and McDonald Creeks, respectively. These concentrations are above recommended drinking water standards. Based on specific conductance and SAR values, these waters would have a high sodium hazard and a very high salinity hazard (Figures 7 and 8).

Prairie County

Prairie County, located in eastcentral Montana, has an area of 1,739 square miles including 12 square miles of water. The Yellowstone and Tongue Rivers are the county's major waterways. Topography consists of rolling hills and flat plains. Saline affected acres is placed at 250 dryland and 3,500 irrigated acres.

Sand and gravel terraces are characteristic of the Yellowstone Valley. Prominant geologic formations in the county are Fort Union and Hell Creek Formation, and the Fox Hills Sandstone. Waters high in sodium are produced from the Hell Creek and Fox Hills Formations (Botz, 1970). Soils of Prairie County are variable from dense alkali clay to sand loam soils. Most of the salinity affected acreage is irrigated; thus, the problems in Prairie County are a result of salt leaching by irrigation waters and evapotranspiration.

Four samples were collected from O'Fallon Creek. Moderately high dissolved solids (Table 6) make this stream unsuitable for irrigation and SAR values greater than six were common. These waters have a very high salinity and alkali hazard (Figures 7 and 8).

Richland County

Richland County (2,103 square miles) is located west of the confluence of the Missouri and Yellowstone Rivers. Topographically, this county is mostly plains and rolling hills. Saline affected acreage is recorded at 1900-3,500 dryland and 161 irrigated.

Area geology is dominated by the Fort Union Formation, glacial till and alluvium. Area soils which are contributors to saline seep are Lambert Silt Loam, Lambert Complex (239,000 acres), Vida Zohill Complex, and Zohill loam. A soil type listed as a potential receiving area is the Vida Clay Loam (202,000 acres). A natural occurring alkali loam is the Benz Clay Loam (4,500 acres). (Information personal communication Myron Saylor, Richland County Conservationist).

The two county water sampling sites were Second Hog and Lone Tree Creeks. These waters are sodium and magnesium sulfate type waters, respectively. These waters would be marginal livestock waters and unsatisfactory for irrigation due to high salinity and SAR (Tables 2 and 6).

Roosevelt County

Roosevelt County, in northeastern Montana, has a surface area of 2,399 square miles including 14 square miles of surface water. The topography consists of level plains and rolling hills and major waterways are the Missouri and Poplar Rivers. Reportedly, 12,500 dryland acres are damaged by saline seeps; however, no irrigated acreage has been lost. Much of the county has a thin mantle of glacial till underlain by the Fort Union Formation. Marine such as the Bearpaw Shale also are exposed in the county. Soils are variable ranging from well drained non-alkali to tight alkali soils.

Of the four streams sampled, Lost Creek has the highest values of dissolved solids, nitrates and sulfates (Table 6). A SAR value of 8.2 was observed on the Poplar River; this value is above the recommended irrigation limit. A proposed Canadian power plant may have adverse effects on the Poplar River. This stream has saline problems and reduced flows will further concentrate these salts, thus causing further lowering of the Poplar River's water quality.

Rosebud County

Rosebud County, in eastcentral Montana, has an area of 5,042 square miles including ten square miles of water surface. This water surface consists of the Yellowstone, Tongue, and Musselshell Rivers. Topographically, this county is characterized by rolling hills and prairies. Rosebud County lists no dryland acres lost to saline seep and only 350 damaged irrigated acres. This latter acreage is due to salt accrual in the soils and due to evapotranspiration and poor soil drainage.

Geological formations of importance are Eagle, Judith River, Hell Creek, Fort Union, Bearpaw, and Claggett. Soils vary from clay to clay loams and sandy loams. Probably as a result of their geologic contact, several streams reflect saline qualities.

Due to dissolved solids and sodium concentrations (Table 6), these waters should be only used under careful water management practices. SAR values preclude their continued use for irrigation purposes. Vanadium concentrations at Little Porcupine and Smith Creeks are above recommended limits (Tables 2 and 6). Extensive area coal development may aggravate these stream's "natural" saline characteristics. This aggravation occurs through excessive leaching and exposure of alkaline soils to weathering agents.

Sheridan County

Sheridan County (1,720 square miles), located in northeastern Montana, has 20 square miles of lakes and streams. Sheridan's topography is one of rolling hills and plains. Saline affected acreage is 10,000 to 12,000 dryland and 500 irrigated acres.

As typical of eastern Montana, this county geology is dominated by the Fort Union Formation. Hell Creek and Fox Hills Formations along with the Flaxville Gravels and other geological formations are also present. Much of the county's soils are clayey and poorly drained--the Bowdoin-Frazer Nobe Association is noted for its alkalinity. This county has a history of natural saline waters; however, current cropping practices may be aggravating the salinity problem.

Due to sodium and dissolved solids (Table 6), these waters provide marginal to unsatisfactory uses. A very high salinity hazard and medium sodium hazard are presented by Clear Lake waters. The other samples provide a medium sodium hazard and a high salinity hazard. As some county waters have been historically saline, it is difficult to discern man-caused situations from natural. The difficulty is compounded due to a lack of historical data.

Stillwater County

Stillwater County (1,755 square miles) is located in southcentral Montana. Topographically a varied county, Stillwater has a mountainous to plains type terrain. The Stillwater and Yellowstone Rivers are the county's major waterways. Stillwater County reports 23,000 (largest affected acreage in Montana) acres of saline affected dryland acres.

Geological formations of importance are the Bearpaw Shale, Colorado Shale, and Claggett Formation. The Bearpaw Shale and adjacent dryland farming are probably the largest causes for salinity of Big Lake. Area soils are basically clayey to sandy and are not very permeable. Soils high in alkali such as the Laurel Silty Clay Loam are found throughout Stillwater County.

Two of six water samples contained concentrations of metals not recommended for livestock or for continuous for irrigation. These concentrations were 9.4 mg/l iron and 0.50 mg/l copper (Tables 2 and 6). Recorded concentrations of sodium, chlorides, sulfates and dissolved solids (77,800 mg/l) were among the highest measured during this survey (Table 6) and salinity and alkali hazards are classed as very high.

Sweet Grass County

Sweet Grass County (1,849 square miles) is located in southcentral Montana. Only three square miles are water surface. This county lists 3,500 acres affected by irrigation salinity and no affected dryland acres. Of the three waters sampled (Table 6) none had any abnormal salt or metal concentrations. The area sampled displayed alkali patches all caused by irrigation canal seepage. A comparison of aerial photos shows that this area (in 20 years) has approximately doubled its size (SCS photos). Water seepage is leaching soluble salts resulting in decreasing soil productivity. Irrigation land is primarily affected, thus, it appears the area's salinity problem is one of leaching, evapotranspiration, and poor water management practices.

Teton County

Teton County (2,294 square miles) is located in the northwestern portion of Montana. Topographically a varied county, with a mixture of plains, rolling hills, and mountains. Dryland and irrigated saline acreage is estimated at 1,600 and 2,789 acres, respectively.

Water samples were collected near Priest and Freeze Out Lakes. Soils in this area are characterized as the Bainville Loams, Scobey Silt Loams and alluvium. Colorado Shale is a dominant geological strata.

Selenium was the only metal observed at a hazardous concentration (Tables 2 and 6). A nitrate concentration of 2,304 mg/l (Table 6) was the maximum measured during this project. This concentration would undoubtedly be lethal to any wildlife or livestock (Table 2). Due to dissolved solids, two samples would be classified as brine. Extremely high concentrations of sodium, nitrate, and sulfate render these waters unsatisfactory.

Toole County

Toole County (area 1,965 square miles) is located in northern Montana. Of the total area, 15 square miles is water surface. Topographically, the county is dominantly rolling hills. Toole County has reported 600 saline affected dryland acres.

Geologically, the county is dominated by the Colorado Shale Formation. Soils adjacent to sampling sites were identified as Scobey Stoney Loam and Phillips Loam. The Scobey Stoney Loams have developed from glacial drift and are underlain by marine shales, a contributing factor to saline seeps.

At Hilger Coulee, selenium concentrations in water are toxic (1.3 mg/l) (Tables 2 and 6). Values of 161,193 mg/l and 117,619 mg/l were recorded for dissolved solids and sulfates, respectively. The preceding parameters were the highest recorded throughout this survey. Nitrate values of 1,019 and 394 mg/l are beyond maximum limits for livestock and human consumption. All waters sampled would be unsuitable for livestock and crops. The analysis indicates there are few beneficial applications for these waters.

Hilger Coulee seep (near Ethridge) flows into the Marias River; it has not been determined what effect this coulee has on the Marias' water quality. Toole County also has a historical record of alkali areas.

Treasure County

Treasure County (997 square miles), located in southcentral Montana, is characterized by rolling plains and has 200 acres of irrigated land affected by saline.

Bearpaw and Claggett Shales are present; however, leaching from these marine formations is currently having no known effect on soil productivity. The latter is indicated by there being no reported dryland salinity affected acreage. The Marias-Pierre-Hoven Association is a deep saline-alkali clay soil in Treasure County. The water quality of Sarpy Creek (Table 6) is probably a reflection of the adjacent geology and soil types.

The SAR and dissolved solids values indicate these waters would be marginal irrigation waters (Tables 2 and 6). A concentration of 0.53 mg/l vanadium (Table 6) is beyond the recommended concentrations for livestock or crops.

Area residents (personal communication) stated that several wells have gone "bad" in Treasure County. It has been reported that these wells are being recharged by nearby irrigation canals. Canal seepage is undoubtedly leaching salts, which are seeping into these downgradient wells. These wells have reportedly gone "bad" within the last 20 years. Additional groundwater sampling and salinity measurements are needed for Treasure County.

Valley County

Valley County (5,104 square miles) is located in northeastern Montana. A portion of Fort Peck Reservoir comprises most of the county's surface water. Topographically this county is rolling hills and plains. Saline affected acreage is estimated at 800 dryland and 3,500 irrigated acres.

Bearpaw Shale is the county's dominant geological feature. Alkali and clayey type soils combined with the presence of marine shales are conducive to saline seeps.

Of 11 water samples, only three contained excessive salts (Table 6). Concentrations of metals were not detrimental to any beneficial use (Tables 2 and 6). Newby Pond area is listed as a classic seep area (by the local conservation agent) and the adjacent cropland has been labeled unsuitable due to saline seeps. The sampled pond in this seep area reflects these saline qualities. Four reservoirs were sampled because of reported fish kills. It was believed these kills were a result of salinity related fish deaths.

Information from the Department of State Lands lists six ponds in Valley County that no longer support fish. Cattle reportedly have died from consuming these waters (personal communication Les Pederson, State Lands Department 1974). The latter deaths probably are a result of nitrate poisoning. Further investigation of these waters is required.

Wheatland County

Wheatland County has reported 30 acres of saline affected irrigation land. This problem is related to salt accumulation via irrigation waters. The accrued effects of these salts are more visible in the Musselshell River near Mosby (see Petroleum County).

None of the five water samples collected from Wheatland County contain metals in concentrations deliterous to beneficial uses. However, analysis of three water samples indicate salt problems (Table 6). Any further conclusions would require a more complete chemical analysis.

The presence of the Claggett and Colorado Formations coupled with clayey soils suggest that saline seeps may become a problem in Wheatland County.

Wibaux County

Wibaux County (891 square miles) is eastcentrally located. This county has two square miles of water surface. Topographically, Wibaux County is characterized by prairies. This county has an estimated 330 salinity affected dryland acres.

The geologic setting is dominated by the Fort Union Formation. Saline uplands and claypan soils are comprised of Moline Clay Loam, Rhodes Clay Loam, and Rhodes Moline Complex.

Dissolved solids (Tables 2 and 6) make these sampled waters suitable for irrigation purposes with careful management practices and acceptable for livestock usage.

Yellowstone County

Yellowstone County (2,611 square miles) is located in southcentral Montana. This county is typified by an undulating topography. Yellowstone County estimates 600 and 2,000 dryland and irrigated saline affected acreages, respectively.

Prevalent geologic formations are Claggett Formation, Lennep Sandstone, Eagle Sandstone and Quaternary alluvium. Soils adjacent to the water sample site are Cushman-Bainville Loams and the Vananda series; the latter contains salts and is strongly calcareous (USDA, 1972). Undoubtedly salinity of this water sample is due to leaching from the adjacent soils. High concentrations of sodium and dissolved solids cause these waters to be unsatisfactory for irrigation purposes and marginal for livestock. As irrigation waters, these waters are classified as having very high salinity and sodium hazards (Figures 7 and 8). Measured metals concentrations are acceptable for most uses.

The mechanism resulting in saline seeps from dryland farmed areas has been described by Bahls and Miller (1973). The basic hydrologic flow diagram for dryland saline seep information (Figure 21) consists of infiltration of precipitation into a salt-laden soil, dissolution of salts from the soil, downward percolation of these salts, lateral movement of the salts within the groundwater, and reappearance of the salt-laden groundwater at the ground surface or at the groundwater discharge point.

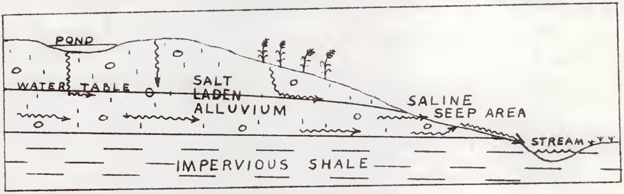


FIGURE 21. DIAGRAM OF SALINE SEEP MECHANISM

Salts in the groundwater are commonly further concentrated by evapotranspiration at the ground surface creating typical white-crusted saline seep area. The basic input of moisture to the system in dryland areas is precipitation. The saline seep phenomona as it has been investigated in most dryland areas is a relatively localized phenomona consisting of water recharge and nearby (within a few thousand feet) discharge area where groundwater is coming to the surface. The system is also characterized by a rather shallow aquifer system.

The exact same mechanism operates in irrigated areas except the input moisture to the system is from irrigation. The percolation, salt dissolution, horizontal migration and discharge to form a saline area is exactly the same as in the dryland farm case.

A situation where salinity can substantially downgrade groundwaters that have not been investigated to date consists of salt-laden soils or glacial till, underlain by a good aquifer that is aerially extensive and relatively deep or underlain at a relatively great depth by impermeable strata. In both these cases, groundwater would enter the soil system, pick up a salt load, percolate downward to either an aquifer or an impermeable strata where the groundwater would move laterally to a discharge point. As the depth to the groundwater table increases, the discharge point may be at a greater distance from the recharge area and unless there are wells situated in the affected aquifer, the impact of salinity may not appear for a considerable time period. This case is diagramically shown in Figure 22.

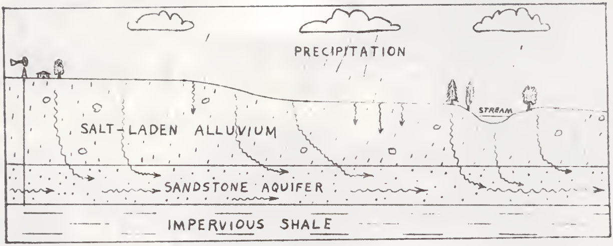


FIGURE 22. GROUNDWATER SALINITY FROM DEEP PERCOLATION OF WATER INTO AN AERIALLY EXTENSIVE AQUIFER

There are substantial areas in Montana where a salt-laden strata are underlain by either an aquifer or by a relatively deeply buried impermeable zone that would allow a long downward movement of salt-laden waters. Saline recharge water would not show up in a discharging groundwater system for a considerable length of time. It is entirely possible that in such cases usage of the water from the saline polluted aquifer would continue until the wells become too saline for use. For most water use, such as irrigation, domestic and stock, little notice is paid to water quality until the water is unsuitable and rarely are there sufficient water quality records to document such changes. Although it has not been substantiated, it is probable that a number of Montana's aquifers are being polluted by saline waters and the salinity impact has not been detected.

The problem of groundwater salinity involves not only quality but also commonly involves increased quantities of groundwater. These increased quantities create rising groundwater tables, additional discharges at springs and seeps and additional flows to streams, ponds, and other groundwater discharge points. This increased discharge creates a variety of problems including greater saline water flows to streams and other water bodies.

To appraise salinity impacts on groundwater, water quality information was examined from a variety of sources. It was hoped that long continuous records would be located that would document salinity trends. It was anticipated that wells in selected areas could be located and resampled to see if there was degradation from salinity. Information from the following sources was examined:

1. Municipal water quality records from the Water Quality Bureau for communities with public water supplies. Some quality analysis were done as early as 1912.

2. County well records on file with the Water Quality Bureau. A large number of private water analysis have been done and filed by the Water Quality Bureau in the last 60 years.

3. Groundwater and hydrology reports of various state and federal agencies that include descriptions of groundwater quality.

4. Records of the Montana Livestock Sanitary Board Diagnostic Laboratory concerning water analysis for livestock.

In addition to these data sources, groundwater salinity was discussed with numerous state, local, and federal organizations and private individuals.

Effort was made to resample wells that showed high concentrations of dissolved solids. Much difficulty was experienced in locating wells that were saline. Many of these wells were abandoned or destroyed. In many areas the old well sites could not be found, land use had changed and the status of the wells were unknown. Groundwater information obtained at communities and in rural areas is incorporated in the discussions of municipal water quality and county groundwater and hydrogeology information.

Water Quality Data from Individual Water Supplies

A large number of water samples from private water supplies have been analyzed in past years by laboratories in Montana including the Department of Health and Environmental Sciences laboratories, the Montana Livestock Sanitary Board Diagnostic Laboratory, and the Soils Testing Laboratory at Montana State University. These laboratories receive a number of samples each year; however, the locations of the sampling points are poorly described and are not related to geographic locations. Locations usually are related to an owner's name and a nearby community or post office. Thus, it has not been possible to resample these water sources due to inadequate locations. Samples received by the Water Quality Bureau prior to 1972 were not thoroughly documented as to location and commonly did not indicate the source of the water nor depth of the well. An extensive examination of the old records indicated that seldom is there enough information to relocate the old sampling points. Due to time limitations and budget limitations, a limited amount of followup was done on these previous sample locations. Of those locations that were followed up, the wells were difficult to locate and many wells were found to be abandoned or destroyed. Thus, the backlog of data for private water samples is virtually useless in evaluation of salinity trends. Since 1972, the Water Quality Bureau has required township, range, section, and quarter-quarter-quarter locations for samples submitted to the laboratory. This will allow future relocation of sampling points.

Another factor that must be considered in groundwater pollution by saline waters is the ability to abate or correct the problem. Groundwater moves slowly--very slowly, a few ten to a few hundred of feet per year. It is expensive to investigate groundwater problems and more expensive to manipulate the groundwater system to correct pollution problems. Commonly there are no economical solutions to groundwater pollution problems. A polluted groundwater system commonly is irreversibly damaged for generations. An important impact of saline seeps may be saline pollution of extensive bodies of groundwater, thus possibly destroying this water for many uses for future generations.

Municipal Water Quality Data

In Montana there are approximately 149 communities that use groundwater from wells or springs as their water source. An additional 13 communities use groundwater in conjunction with a surface water supply. Five communities use infiltration gallerys that remove groundwater by means of a large underground horizontal opening. The Water Quality Bureau has a large number of community water quality records extending back as much as 60 years. A list of towns having saline groundwaters was compiled using the following criteria:

1. The community is in an area of dryland farming or extensive irrigation.
2. The community is near or underlain by salt-laden strata such as glacial till or shales.
3. The community water has salinity problems or reportedly increased salinity.
4. The total dissolved solids exceeded 1,000 mg/l.

Using these criteria, the following communities were delineated:

Bainville
Big Sandy
Broadview
Brockton
Circle
Coffee Creek
Cut Bank
Devon
Fairview
Flaxville
Frazer
Froid
Geraldine
Glasgow
Havre
Hinsdale
Huntley
Jordan
Judith Gap
Kevin
Lambert
Medicine Lake
Melstone
Musselshell
Nashua
Plentywood
Plevna
Rapelje
Roundup
Ryegate
Saco
Scobey
Sunburst
Vaughn
Wibaux
Wyola

BIGHORN COUNTY

Wyola

Wyola is located in southeast Bighorn County 10 miles north of the

Wyoming state line. The present population is 130. Water supply is obtained from a dug well with a capacity of 50 gpm. There are 5 water quality analysis of the municipal supply going back to 1936. From these samples no long term trend in TDS is obvious.

CASCADE COUNTY

Vaughn

Vaughn is 10 miles west of Great Falls and has a population of 200. Water supply for Vaughn is derived from two drilled wells approximately 100 feet deep, located southwest of town. There are 20 water quality analysis for Vaughn going back to 1932. Of these analysis only four have specific sample descriptions. There is moderate dissolved salts in these samples averaging about 1,100 mg/l. From this small number of samples it is not possible to make any conclusions about salinity trends.

CHOUTEAU COUNTY

Big Sandy

Big Sandy is located in northeast Chouteau County along Big Sandy Creek. The estimated 1970 population is 1,042. A central water system is in operation and consists of 15 different shallow wells with a combined capacity of about 200 gpm. There are about 100 water quality analysis for wells in Big Sandy starting in 1929. It is impossible to consistently match these analysis to a specific well since exact locations are not given. A survey for the Prairie Water Users Association in January of 1974 tried to find wells with a greater flow. The seven well samples sent in for analysis all had dissolved solids of 600 to 700 mg/l. At present the water quality of Big Sandy does not seem to be affected by saline seep.

Geraldine

Geraldine is located in eastern Chouteau County 8 miles north of Square Butte. The estimated 1970 population is 200 people with a decline expected in the next 25 years. The community water system is supplied from three wells with a combined capacity of 235 gpm. This water system yields adequate quantities of good quality water to each resident. Of the many analysis dating back to 1957, TDS is low and there seems to be no problem with saline water.

DANIELS COUNTY

Scobey is located in the center of Daniels County along the Poplar River. The 1970 population is estimated to be 1,775. A central water system serves the town and consists of three wells with a combined capacity of 900 gpm. These wells are about 40 feet deep and are located west of town. Complete water analysis for the municipal water supply in Scobey go back to 1939 and up to 1966. There is no fluctuation in TDS and water quality is relatively good.

Flaxville

Flaxville is located 11 miles east of Scobey on Highway 5 in Daniels County. It has an estimated population of 250. A community water facility is presently in operation consisting of two wells with a combined capacity of 700 gpm. This water system was first installed in November 1957 when the first 50 foot well was drilled. There are 56 water analysis available for the Flaxville water supply but these are not complete analysis. The majority of analysis are for nitrates, the wells have 85 to 190 mg/l nitrate as NO_3. Complete chemical analysis for 1966 and 1967 show that well #1 had a TDS of 780 and well #2, 1270 mg/l. This is a moderately high total dissolved solids but this is not unusual for municipal water in northeastern Montana. The most urgent problem at present seems to be high nitrates possibly caused by seepage from agricultural lands or from seepage of sanitary waste waters.

FALLON COUNTY

Plevna

Plevna is located 13 miles west of Baker along Highway 12. The estimated 1970 population of Plevna is 200. The water system is supplied by two wells located within the community and capable of producing 75 gpm. Water from these wells is of good quality and no treatment is provided. There are no complete water analysis for this municipal supply so no salinity trends can be identified.

FERGUS COUNTY

Denton

Water for the town of Denton is derived from springs located on Coyote Creek about 1.5 miles west of the airport. Water quality analysis for this town show a dramatic increase in nitrates from 1961 till the last complete analysis in 1973 (Figure 23). There are two possible reasons for this, one could be nitrogen fertilizers and the other, saline seep. It is unlikely that saline seep is the cause because there has been no similar rise in total dissolved solids during this ten-year period. These springs were still being used in 1974 and the last complete analysis in May of 1973 showed nitrates at 75 mg/l. There is considerable dryland farming in this area and saline seep is an extensive problem. Saline water has caused stock waters and wells in Fergus County to become unusable and the location of the Denton municipal springs would make it susceptable to saline seep.

Coffee Creek

Coffee Creek is located along Highway 215, 7 miles north of Denton. The 60 residents of Denton presently obtain their water supply from a developed spring located northwest of the community. Water quality analysis show moderate TDS (1000 mg/1) and a large increase in nitrates over the last 10 years (Figure 24). During this sudden rise in nitrates

Figure 23. Composite of Yearly Nitrate Levels in the Denton Municipal Water Supply

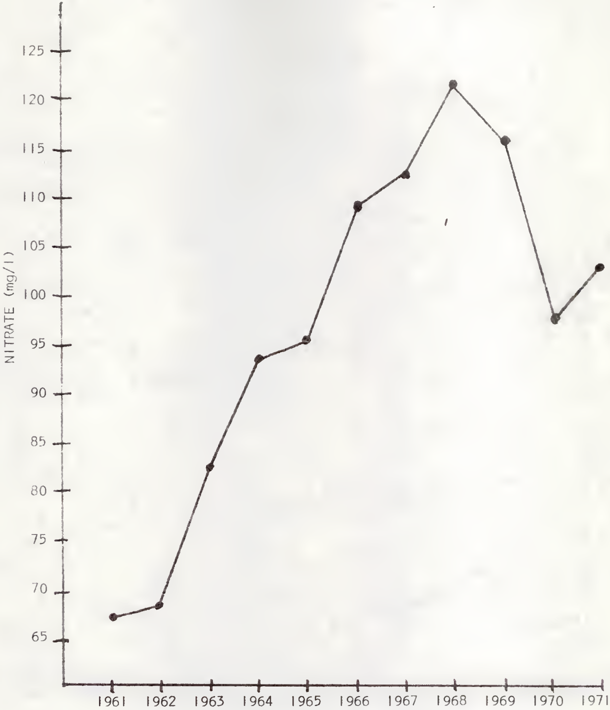
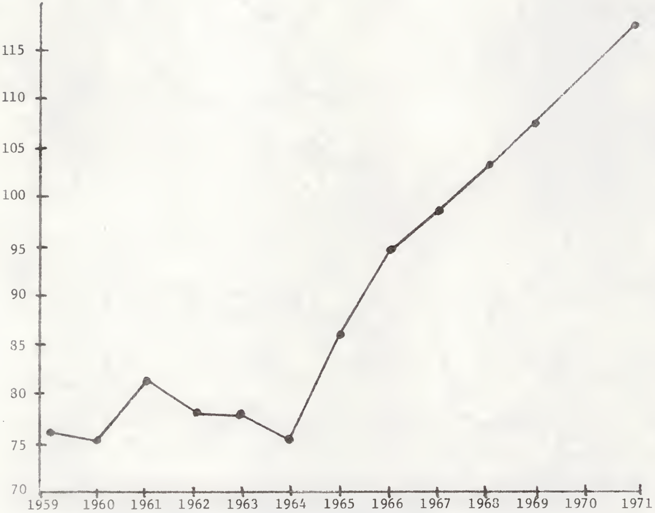


Figure 24. Composite of Yearly Nitrate Levels in the Coffee Creek Municipal Water Supply



there has been no corresponding increase in total dissolved solids. The areas around the springs is low and rolling with extensive dryland farming and this increase in nitrates appears to be related to agricultural runoff of some type.

GARFIELD COUNTY

Jordon

Jordon is the county seat of Garfield County and is located along Big Dry Creek. The estimated 1970 population is 550. Water supply is obtained from one well which has a capacity of 175 gpm. Water quality is poor because of high total dissolved solids. The area around Jordon is mostly range land and there is little possibility that saline seep had caused these high solids which range in concentration from 1900 to over 2000 mg/l. Water quality analysis dating back to 1924 shows no increase in TDS during this 50-year period.

GLACIER COUNTY

Cut Bank

Cut Bank, located in eastern Glacier County along Cut Bank Creek, has an estimated 1970 population of 4,790. The supply of water is obtained from Cut Bank Creek. An emergency well is maintained to supplement output from the water treatment plant if the need arises. Dissolved solids in this well doubled from 1964 to 1965 and the well became unusable (Figure 25). This was probably due to a nearby oil well which may have contaminated the groundwater with salty water.

GOLDEN VALLEY COUNTY

Ryegate

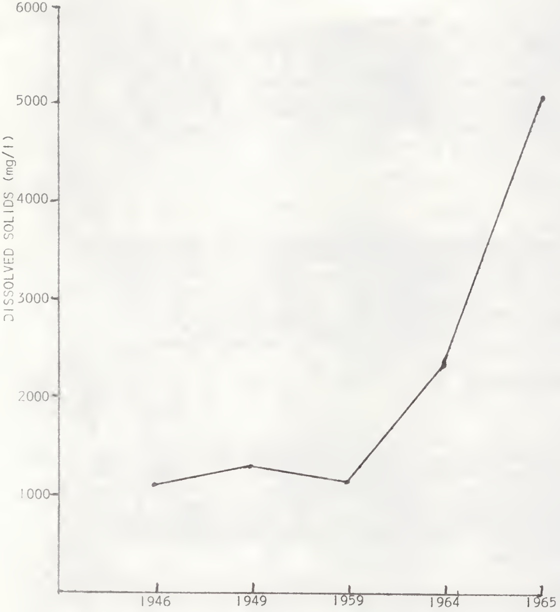
Ryegate is the county seat of Golden Valley County and is located along the Musselshell River. The present population is 275. Water supply is from an infiltration gallery located south of town along the Musselshell River. This facility has two pumps with a combined capacity of 250 gallons per minute. There are 26 chemical analysis for Ryegate wells dating back to 1932. Of these, only three are mentioned as being from a city well. No conclusions can be drawn from this limited data.

HILL COUNTY

Havre

Havre is located in eastern Hill County and has a population of 10,558. The water supply for Havre is derived from an intake on the Milk River and three wells in town. There are 156 analysis on wells in Havre dating from 1919 to 1975. Descriptions of samples are accurately given over this 56-year period. There does not seem to be any trend in total dissolved solids. The water samples vary from 900 to 1300 mg/l in TDS but no salinity increase is apparent.

Figure 25. Changes in Dissolved Solids from a Cut Bank Well (Zimmerman, 1967).



McCONE COUNTY

Circle

Circle is the county seat of McCone County and is located along the Redwater River. The estimated 1970 population is 1,162. Water supply is presently obtained from three wells with a combined capacity of 145 gpm. Water quality is only fair since it is high in total dissolved solids. There are a total of 82 analysis for the town of Circle dating from 1930 to 1971. Well depths range from a 100 foot to over a 1,000 foot. Descriptions of samples are inadequate and identifying a specific well over a period of time is not possible. Total solids have been high in the Circle water since the early 1930's and there has been little change.

MUSSELSHELL COUNTY

Melstone

Melstone is located in Musselshell County along the Musselshell River 34 miles downstream from Roundup. The 1970 population is estimated to be 250. Water supply is obtained from an infiltration gallery along the Musselshell River having a capacity of 300 gpm. There are 15 analysis dating back to 1926 but only three of these were definitely identified as coming from a city supply. The location of the sampling points are not clearly identified, thus no salinity trends can be determined.

Musselshell

Musselshell is in eastern Musselshell County along the Musselshell River. The 1970 population is estimated to be 30 people. The water supply system for Musselshell consists of a single drilled well about 120 feet deep and equipped with a submersible pump. If the nine available analysis for the city well are from the same source, there has been a significant increase in total dissolved solids since 1920 (See Table 7).

Roundup

Roundup is the county seat of Musselshell County and is located along the Musselshell River. The water supply at the present time consists of two wells with a combined capacity, 1,250 gpm. There is also an infiltration gallery near the Musselshell River. Water quality analysis for wells in the Roundup area extend from 1922 to 1974. Ten analysis can be identified as being from a municipal supply. These 10 analysis come from various municipal wells and descriptions are not consistent enough to be able to trace trends. Total dissolved solids are moderately high (about 1200 to 1600 mg/l) but this would be considered average water quality in this part of Montana.

PHILLIPS COUNTY

Table 7

Musselshell, Montana

Period of Record--11/19/19 to 2/9/74

Analysis--22

Date	TDS	Source
12/16/70	1916	Water Resources Board
5/--/69	1550	
6/10/65	2054	Town well
5/17/63	1256	Town well
4/14/59	1395	Town well
7/10/53	1180	City supply
12/29/32	1707	City supply
1/17/30	1181	City supply
9/14/20	1014	City supply

Saco

Saco is located along Highway 2 near the Milk River. Water from the town is derived from two wells located northwest of the community. The Schelle Well (north well) is approximately 21 feet deep with approximately 3 feet of standing water in the well. The Blue Well (south well) is approximately 15 feet deep with 3 feet of standing water. There are 36 well analysis of Saco wells and springs going back to 1920. In these analysis it is not mentioned whether the sample is from either the Schelle Well or the Blue Well. The Schelle Well operates in a very interesting manner. An irrigation canal or ditch runs near the well. From this ditch water is allowed to enter a small natural swamp or swail area adjacent to the canal. Here a pump unit has been installed which lifts the water into natural sand and gravel beds. Four or five days later the water seeps into the well 200 feet away. This spring should be a good indication of problems from saline irrigation water in the Saco area. The data, however, shows a variable and erratic quality and no conclusion concerning salinity trends can be made.

RICHLAND COUNTY

Fairview

The town of Fairview is located in eastern Richland County on the North Dakota border. The water supply for Fairview presently consists of two wells which produce about 200 gpm. There are a total of 36 analysis on this water supply since 1924. Exact locations of various wells are not given and evaluating trends in total dissolved solids is not possible.

Lambert

The town of Lambert is located west of Sidney on Highway 200. This town of 250 has recently installed a community water system. The only complete analysis is for well #2 in 1971 which had TDS of 3,160 mg/1. Field reports on the Lambert water supply system indicate that it has been impossible to find a well with good water.

ROOSEVELT COUNTY

Bainville

The community of Bainville is located in the southeast corner of Roosevelt County along Shotgun Creek, an intermittent stream about seven miles north of the Missouri River. The area is an ancient channel of the Missouri River and there is extensive dryland farming nearby. The community has a present population of 250 and the population is declining. A community water system is in existence and consists of three wells. Two of these wells are in use and the third well, located near the center of town, is not being used. Of the two wells that are used, one is located near the center of town and is producing approximately 13.5 gallons per minute; the second well is located by the city center and is producing approximately 10 gallons per minute. A total of 19 chemical analyses are available from the Water Quality Bureau for the Bainville water supply dating from 1935 to 1968. Descriptions of the sampling sites have not been consistent and it is difficult to compare analyses due to problems of determining which wells match which chemical analyses. Also some water samples were from a tap and not a specific well and some analyses were from test wells. Water in the community has always had a moderate to high total dissolved solids content. In the chemical analyses history, two wells - Well 1 and Well 2 - have been recorded at two separate times. These data are shown below.

Well 1:	TDS	Ca	Mg	Na	HCO_3	SO_4	Cl	NO_3
10/15/35	2,030	91	95	498	867	920		7.5
8/10/66	4,930	592	306	525 (Na+K)	610	3,120	84	0.0
Well 2:								
10/15/36	615	103	40	34	349	175	15	0.0
8/10/66	1,260	266	34	90 (Na+K)	378	640	12	

If the description for wells 1 and 2 are accurate and consistent, there has been at least a 100 percent increase in salinity in these wells during the 31-year period.

Brockton

The estimated 1970 population is 395. A community water system facility presently provides service to all residents and consists of two wells with a combined capacity of 130 gpm. Information is not available on the depth of the two Brockton wells but they have been in use since 1955. There are 11 analysis in the Brockton area. Well locations are not identified and are referred to by the private residence from where they were sampled. Even if the records are from different sources, the TDS are moderately low and other parameters do not indicate problems with saline water. Brockton is located on the Fort Peck Indian Reservation and is on the flood plain of the Missouri River. At this time there seems to be no indication of saline water damaging the Brockton water supply.

Froid

Froid is located in the northeast section of Roosevelt County 13 miles north of Culbertson. The water supply for Froid is obtained from two drilled wells located two miles west of town. Both wells are approximately 70 feet deep and together produce about 200 gallons per minute. Examination of old water quality data and field reports shows that in 1951 Froid had four wells and numerous private wells. In November, 1952, a sample was sent in for a nitrate analysis from the private well of Mr. C. L. Ehard. This water contained 498 ppm nitrate and was suspected of being responsible for the death of a five week old infant from methemoglobinemia. Further investigation of wells in the vicinity showed that city wells which were over 100 feet deep had less than 20 mg/l nitrates and the shallow wells of 20 to 15 feet contained 220 to 550 ppm nitrates. The cause of the high nitrates was related to sewage. The shallow wells were discontinued and a new well was drilled in October, 1955. This well is 2 miles west of town, 125 feet deep, and produces 125 gpm. Prior to 1955 there were approximately 56 water quality analysis from area private and municipal well samples. The location of sample sites are only identified by the individuals who requested analysis, or if it was a city well--just a notation--city well. An appraisal of these samples shows high total dissolved solids of 1,000 mg/l to over 2,000 mg/l. A random selection of the 12 analysis on the well drilled west of town in 1955 shows water high in TDS, sulfate, and sodium. A new well was drilled in August, 1973 one mile west of town. The new well is 57 feet deep and pumps 80 gpm. Analysis from this sample show the same saline qualities as the previous wells. The Froid area is extensively dryland farmed; however, due to Froid's historically bad water, farming practices may not be responsible for the salinity.

SHERIDAN COUNTY

Medicine Lake

The town of Medicine Lake is located in the southwest corner of Sheridan County 20 miles south of Plentywood on Highway 16. The present population is estimated to be 542. A community water system is in operation. Water supply is obtained from a well which is pumped at 300 gpm. This well is 59 feet deep and is located in the west part of town. Field reports on the water system of Medicine Lake starting in 1921 refer to a dug well 14 feet deep and 10 feet wide. This well was used until August 24, 1959, when it was abandoned due to structural problems. Analysis from this dug well show an increase in TDS as follows:

DATE	TDS
2/26/18	292
3/21/30	412
10/10/38	695
5/1/46	1198
6/15/54	1180

This increase may be caused by several factors including backup of saline surface water from Medicine Lake Refuge, seepage from Big Muddy Creek, or seepage of water from agricultural lands. Medicine Lake is in a flood plain formed by Muddy Creek and there are many alkali spots scattered in the nearby fields and hay meadows. Water in the newly drilled well is moderately high in total dissolved solids and from the four analysis available since 1959 there does not seem to be much fluctuation in water quality.

Plentywood

Plentywood is located in the center of Sheridan County along Big Muddy Creek. The present population is 2,330 and this is expected to increase slightly in the next 25 years. The town is served by a central water system. Water supply is obtained from six wells with a total capacity of 900 gpm. The number, depth, and yield of each well is:

Well	Depth	Yield
#1	Abandoned	
#2	73 feet	115 gpm
#3	167 feet	125 gpm
#4	68 feet	115 gpm
#5	71 feet	85-115 gpm
#6	56 feet	250 gpm
#7	71 feet	85 gpm

Water quality is only fair due to high total solids and hardness. An early Department of Health field report, July 30, 1919, on the Plentywood water supply states, "The city water contains considerable mineral matter in solution, in a form called alkali." The water quality has not changed in the past 56 years since this report was filed and the municipal supply of Plentywood is still high in total dissolved solids. Tracing the trend in any particular well is impossible since exact locations are not given with the analysis. A random selection of the 60 analysis indicates the water is consistently high in total dissolved solids.

Plentywood lies in the flood plain of Big Muddy Creek. Terrain along sides of the stream valley consists of eroded gullies with shale outcrops. (Salt stains many shale outcrops. Dry coulees leading down to the river are white with alkali.) How this may affect the Plentywood water supply is not known.

STILLWATER COUNTY

Rapelje

Rapelje is in northcentral Stillwater County near the Hailstone National Wildlife Refuge. The water supply for the 72 residents of Rapelje is obtained from a spring at the southeast edge of town. The last complete analysis for this spring in 1969 indicates a TDS of 2130 mg/1 which is high. This has not changed significantly since the complete analysis in 1963 which showed a TDS of 2012.

TOOLE COUNTY

Devon

Devon is located in eastern Toole County 19 miles east of Shelby on Highway 2. The estimated 1970 population is 40. The residents presently find it necessary to have their water hauled from Shelby. Groundwater in the area is not fit for human consumption. There are no water quality records for this town.

Kevin

Kevin is located 14 miles northwest of Shelby just off Interstate 15. Kevin has an estimated 1970 population of 457. Water supply is obtained from wells and one spring located about 10 miles west of town. The combined capacity of the water system is 120 gpm. Considerable water shortage has been experienced in past years. The demand for water is derived from domestic use, the industrial demand of an oil refinery and the rural population which hauls water from the town. A new 78 foot well was recently drilled and provides 18 gpm. The 42 water quality analysis for the municipal spring and wells date back to 1926. The total dissolved solids on these samples are low ranging 400 to 800 mg/1 and there is no discernible upward trend in TDS as of the last complete analysis in 1971.

Sunburst

Sunburst is located in northern Toole County 27 miles north of Shelby on Interstate 15. The estimated 1970 population is 875 persons. The community water supply is obtained from two wells located 15 miles west of town. Well No. 15 is located in Section 1, Township 36 North, Range 5 West, and is 441 feet deep. This well produces 125 gpm and furnishes all the water for the town. Well No. 1 is a standby well and is located in Section 14, Township 36 North, Range 4 West. Several other wells are also owned by the city in this area but are not operational.

There are a total of 64 analysis for Sunburst from 1925 to 1971. In that time Sunburst has drilled several wells and exact locations for these wells are not given with the chemical analysis. Samples sent for analysis show a TDS range of 730 to 1300 mg/1.

TREASURE COUNTY

Hysham

Hysham is located along the Yellowstone River and is the county seat of Treasure County. The water supply is two infiltration wells next to the Yellowstone River. These wells produce a total of 250 gpm. Water quality analysis for Hysham go back to 1917. Seventeen analysis are identified as a city water supply. Locations of these samples are not well described. Total dissolved solids vary from 600 to 6,402 mg/l. Hysham has had problems with wells supposedly going bad from a rapid rise in total dissolved solids. This may be caused by irrigation infiltration. There has been no documentation of any well salinity problem in Hysham. A visit was made to Hysham but it was not possible to locate the older community wells.

VALLEY COUNTY

Nashua

Nashua is located in the southeastern corner of Valley County at the confluence of the Milk River and Porcupine Creek near the Missouri River. The estimated 1970 population is 750. The area is presently served by a community water system consisting of a 56 foot deep well which produces 670 gpm. Water quality records from 1919 show water as being moderately high in total dissolved solids. Records are confusing until about 1937 when there are indications that the town supply was coming from one source rather than a variety of private wells. This well was used until 1975 and does show an increase in TDS. There are not enough analysis to warrant any conclusions. All along the Milk River Valley there is irrigated farming. Irrigation water passes over alkali soils and causes problems with infiltration of saline water. There is a possibility that this may be affecting the Nashua water supply system.

Date	TDS	LOCATION
2/27/37	970	City well 1,000' west Front St. Well #1
9/23/37	1970	City well
10/27/53	1600	City supply
9/8/59	2390	City
12/31/70	2190	City well
5/30/71	2140	City well

Frazer

Frazer is located 19 miles west of Wolf Point along Highway 2 along the Missouri River. The 1970 population is estimated to be 410. A community water system was installed in 1969. Water supply is obtained from two wells with a combined output of 45 gpm. Insufficient data are available to determine salinity trends in these wells.

Glasgow

The town of Glasgow is the county seat of Valley County and is located along the Milk River. The estimated 1970 population is 4,700. The water supply system for Glasgow consists of four wells with varying capacities ranging from 500 to 900 gallons per minute. The wells vary in depth from 110 to 120 feet. There are 118 analysis starting with the year 1918 to 1971. The numbering system for the well seems consistent and because of this it is possible to trace an increase in TDS as shown below:

Well #1		Well #2		Well #3	
7/28/48	920	10/28/53	1095	11/2/61	1230
10/28/53	940	12/26/56	1096	8/31/65	1150
12/26/56	968	11/2/61	1240	5/18/71	1318
11/2/61	1070	8/31/65	1278	3/7/73	1514
8/31/65	1008	5/18/71	1412		
5/18/71	1102				

These increases are not large but they may indicate that saline waters are starting to affect this supply. This town is in the Milk River Valley where there is extensive irrigation. This irrigation water flows over alkali soils and the return flows are probably alkaline.

Hinsdale

The town of Hinsdale is located along Highway 2, 42 miles west of Glasgow. The estimated 1970 population is 370. The community system is served by a 30 foot dug well which is one-half mile east of town. This well became operational in 1953 and produces about 300 gallons per minute. Chemical analysis from this well start in 1953 and go to 1971. The total dissolved solids in the water are moderately high but for a shallow well in northeastern Montana this is not unusual. Hinsdale is in the Milk River Valley where there are reported irrigation salinity problems. The data does not show any distinct trend in the Hinsdale water salinity.

WHEATLAND COUNTY

Judith Gap

Judith Gap is in the northcentral part of Wheatland County just off Highway 191. The estimated 1970 population is 160. A community water system is presently in existence consisting of two wells with a combined capacity of 190 gpm and a depth of 125 feet. Water quality analysis shows water high in total dissolved solids ranging from 1300 to 1800 mg/1. The 14 analysis dating back to 1918 and up through 1969 show little variation in TDS. This area is surrounded by extensive dryland farming and saline seep has been reported in this county but apparently is not affecting water quality in Judith Gap.

WIBAUX COUNTY

Wibaux

Wibaux is the county seat of Wibaux County and is located along Beaver Creek. The estimated 1970 population is 775. Water supply is presently obtained from four wells with a combined capacity of 250 gpm. There are 53 analysis on wells in Wibaux. Locations of the well samples are well documented and there is no upward trend in TDS in these wells for the past 25 years.

YELLOWSTONE COUNTY

Broadview

Broadview in northwest Yellowstone County is 32 miles north of Billings on Highway 3. The present population is 120. The town is presently served by a community water system consisting of a well 1,000 feet deep which produces 35 gpm. The depth of this well precludes changes in quality due to salinity. Chemical analysis from past municipal wells do not have adequate descriptions; thus salinity trends cannot be evaluated.

Huntley

Huntley is 10 miles east of Billings on Interstate 191. The town has a population of 400 and is served by a community water system consisting of a single well 145 feet deep. Water quality analysis show no trend in TDS.

In conclusion, the search through the Water Quality Bureau files for water quality analysis from municipalities that may be in saline affected areas provided data on 35 communities. These data indicated problems in 14 communities, no problems in 12 communities, data was insufficient to assess the status of 9 communities. Problems in the 14 communities includes high nitrates, a substantial increase in total dissolved solids, presence of brine waters from oil drilling, or nearness to saline areas that may result in increasing total dissolved solids. None of the data could conclusively prove deteriorating water quality due to saline seep or irrigation salinity. Increased salinity due to agricultural practices appear, however, to be the probable cause of increased salinity in community water supplies. There are many chemical analysis available for each community, but location descriptions commonly are incomplete or missing, thus much of the data is not usable. Results of this investigation of municipal salinity increases are summarized below.

Municipalities with water systems affected by saline water or in areas with saline seep problems:

Bainville - increase in TDS

Coffee Creek - nitrate increase

Cut Bank - unusable well due to brine pollution

Denton - nitrate increase

Devon - groundwater unfit

Flaxville - high nitrates

Froid - high TDS, past nitrate problem

Glasgow - increase in TDS

Lambert - water high in TDS

Medicine Lake - increase in TDS in old well

Musselshell - increase in TDS in old well

Nashua - increase in TDS in old well

Rapelje - springs high in TDS

Saco - well near an irrigation ditch possible contamination from saline water

Municipalities with insufficient data to determine water quality trends:

Big Sandy
Broadview
Circle
Fairview
Frazer
Geraldine
Roundup
Vaughn
Wyola

Municipalities that have water supplies with no upward trend in total dissolved solids:

Brockton
Havre
Hinsdale
Huntley
Jordon
Judith Gap
Kevin
Plentywood
Plevna
Scobey
Sunburst
Wibaux

COUNTY GROUNDWATER INVESTIGATIONS

Field examinations were conducted in 36 counties to assess the problem of groundwater salinity. All available technical reports concerning groundwater quality (approximately 100) were reviewed. These reports provide historical information on groundwater quality and serve to delineate areas of saline groundwater. Many reports described water quality in deep aquifers (several hundred feet deep) that are of less immediate concern than are shallow aquifers. In examination of the historical groundwater quality data from previous reports, particular attention was given to areas in or near dryland or irrigated cropland. Also of interest, were areas known to have salinity problems and areas where groundwater salinity exceeded 2,000 umhos/cm at 25°C. Data from individual water samples submitted to the Water Quality Bureau also were examined for each county, and those samples with good location data were evaluated. Based on the examination of past reports, attempts were made to resample selected wells; however, most of these wells could not be relocated or were destroyed or abandoned and could not be resampled.

Emphasis on groundwater was placed on resampling old wells from which previous quality data were available. It was hoped that such sampling would determine areas of groundwater salinity changes. Resampling efforts were commonly futile due to well abandonment. Sampling of wells with no previous quality information was considered of secondary importance since salinity trends were the major focus of this study. Limited project budget did not allow an excessive amount of time to be spent on relocation of old wells. It is anticipated that substantial groundwater baseline data will be obtained as part of the Water Quality Bureau - Montana Bureau of Mines saline seep program. The following is a county by county narrative of groundwater salinity conditions.

BIGHORN COUNTY

Tom and others (1935) decribed the geology of Bighorn County and quality of water in that county. Water quality associated with marine shales was generally poor; however, quality of these waters seemed to be determined by natural conditions and was was not affected by agricultural practices. Moulder and others (1960) examined groundwater in the Little Bighorn River Valley. They found that there were poor quality groundwaters in this area; however the groundwater sampling was not extensive and causes of salinity were not investigated sufficiently to determine the relationship to agricultural practices.

In a discussion of geology and groundwater resources of the Lower Bighorn Valley, Hamilton and Paulsen (1968) concluded that concentrations of dissolved solids in waters from alluvial aquifers range from 605 mg/l from a well on a nonirrigated terrace to 7,240 mg/l for a well on an irrigated terrace. They concluded that the concentration of dissolved solids at some placeson the irrigated terraces had increased as a result of poor drainage and evapotranspiration. Typical analyses of groundwater (Table 8) show the water to be unsuitable for many uses. The authors concluded that chemical quality of groundwater in allivium under irrigated land could gradually improve if better drainage could be developed. Thus salinity of groundwaters was significantly impacted by irrigation in this area. Hopkins (1973) examined water quality on the Northern Cheyenne Indian Reservation in Bighorn

County. Results of this work showed considerable salinity in groundwater with some shallow aquifers containing very poor quality waters. Causes of this salinity were not determined.

BLAINE COUNTY

In the evaluation of groundwater resources of Blaine County, Zimmerman (1960) sampled wells in alluvium near the Milk River that had high salinities. (Table 8) The Milk River Valley has continuing problems with irrigation salinity however the relationship of this salinity to saline seeps or irrigated agriculture has not been fully determined.

CARBON COUNTY

This county has extensive problems with irrigation salinity. Water samples obtained from this county have high salinities and one sample had a nitrate concentration of 63 mg/l which exceeds USPHS Standards. (Table 8) The relationship of these waters to saline seeps is unknown.

DAWSON COUNTY

In a discussion of groundwater resources in the Lower Yellowstone River Valley, Torrey and Swenson (1951) showed water from seeps along the Yellowstone River between Fallon and Glendive to have high specific conductance (Table 8). Relationship of the water to irrigation was not determined. Moulder, Torrey, and Koopman (1953) concluded that groundwater quality was markedly poor than river water use for irrigation at the Buffalo Rapids Irrigation Project along the Yellowstone River. The increased mineral content was the result of solutions of minerals in the ground by groundwater and concentration of these minerals by evaporation. Chemical analyses of this water (Table 8) shows it is poor in quality and the conductance varies from about 1300 mg/l to over 4000 mg/l. Quality of the water seems to be significantly impacted by irrigation usage. The present condition of groundwater in this area and the exact relationship to irrigation is unknown. Groundwater data available from the Water Quality Bureau indicates poor quality waters in Dawson County with one sample having a nitrate concentration of 360 mg/l (Table 8).

FALLON COUNTY

Fallon County has significant problems due to saline seeps. Groundwater analyses (Table 8) indicates salinity in the groundwater system; however, depths of these wells are unknown, therefore the relationship to salinity problems is not determined. One well sampled in Fallon County was located at the bottom of low hills surrounded by shale outcrops. Land around the well is no longer farmed because of a rising groundwater table and saline seeps. Sample of water from the well showed a high concentration of dissolved materials and iron, zinc, and manganese exceeded limits set for domestic stock and irrigation water.

GARFIELD COUNTY

In an evaluation of prospects for developing stock water supplies in northern Garfield County, Van Lewen and King (1971) studied groundwaters and concluded that most waters particularly bedrock aquifers contain significant quanities of total dissolved solids. Mineralized water in the area was present in unconsolidated alluvial aquifers. Causes for this salinity were related to geological conditions and no mention was made of the impact of agricultural practices on water quality. Although few saline seep problems have been reported for Garfield County, water analyses from the county show significant salinity (Table 8). It appears that Garfield County has salinity problems that have not been adequately examined.

GLACIER COUNTY

Evaluation of water resources of the Cut Bank area by Zimmerman (1967) indicated poor quality water associated with deeper geological formations in the area. Quality of these waters is probably due to the natural reaction with geological formations in the area. One shallow well in alluvium near the community of Kevin shows significant salinity in groundwater (Table 8).

Paulson and Zimmerman (1965) examined groundwater resources of the Two-Medicine Irrigation Unit west of Cut Bank, Montana. The authors concluded:

> "Water supplied by the Two-Medicine canal is of the calcium-bicarbonate type, commonly contains less than 100 parts per million dissolved solids, and is suitable for irrigation. Water draining from irrigated land is 10 to 30 times as mineralized as the applied irrigation water and is of the sodium sulphatebicarbonate."

Although irrigation significantly affects salinity of this water, the water after use is still only moderately mineralized. (Table 8) As described in Section VIII of this report, a municipal well in Glacier County showed a rapid rise in salinity apparently from oil well brine seepage.

GOLDEN VALLEY COUNTY

A groundwater investigation by Ellis and Meniser (1924) showed poor quality groundwaters in the county associated with shale formations. Little sampling was done in shallow aquifers that may be subjected to salinity damage. A well in alluvium along the Musselshell River and a well near Lavina were found by Zimmerman (1956) to be saline (Table 8). Salinity has significantly affected the Musselshell River and both these well sites were revisited to obtain water samples. The well along the river could not be located. The other site was located and resampled and results of the resampling shows no distinct salinity trend. (Table 8)

HILL COUNTY

The Homestead well (T35N06E36AC) is located in a dry coulee. Land surrounding the well is no longer farmed due to saline seep. Water from the well has a relatively low conductivity and low nitrate concentraction, but has high concentrations of copper, manganese, and zinc. (Table 8) Concentrations of metals from this well make the water unfit for some uses including irrigation and domestic use. Relationship of this water quality to saline seep is not known.

LIBERTY COUNTY

This water sample was collected on the eastern side of the county which has several saline seeps. (Table 8) The well is moderately saline, but the relationship to irrigation practices is unknown.

MUSSELSHELL COUNTY

Groundwater samples collected by Ellis and Meinzer (1924) from Musselshell County showed numerous waters with high salinity. These waters, however, were predominantly associated with bedrock aquifers and the poor waters were associated with shale formations. A number of wells were relocated that had originally been described in the report by Zimmerman (1965). These wells, however, were not operating and it was not possible to obtain water samples. Musselshell County is significantly impacted by salinity due to agricultural practices; however, the groundwater conditions in the county are poorly known.

PHILLIPS COUNTY

The water sample collected was not located in a known saline seep area; however, this well water was moderately saline (Table 8).

RICHLAND COUNTY

Torrey and Kohout (1956) examined groundwater resources of the Lower Yellowstone River Valley and concluded that irrigation was significantly increasing dissolved minerals in groundwater in the area. The groundwater, however, was only moderately saline after use in irrigation and was still suitable for many beneficial uses.

ROSEBUD COUNTY

Hopkins (1971) reported results of chemical testing of waters on the Northern Cheyenne Indian Reservation. Results of this testing indicated that both deep groundwater and shallow groundwater in alluvium along the major streams contained significant amounts of dissolved solids. This is probably the result of natural geological causes rather than being related to croplands or irrigation. Renick (1929) discussed groundwater conditions in this county. He noted that irrigation projects along the Yellowstone River substantially affected the quality of groundwater in alluvium along the river. Renick reports:

> "The residents reported that the high mineralization which characterizes the water of many of the shallow wells has been brought about since the surrounding land has been irrigated."

The present impact of irrigation on groundwater probably has not changed greatly from that reported by Renick; however, present conditions in the area are poorly known.

SHERIDAN COUNTY

Both samples were obtained from areas near saline seeps. (Table 8) The waters were also found to be moderately saline. The effect of farming practices on these waters is unknown.

VALLEY COUNTY

Two examples submitted to the Water Quality Bureau from T37N42E12 were from the Milk River Valley which has extensive problems with salinity. The water analysis showed the wells to have excessive concentrations of nitrate. (Table 8)

WHEATLAND COUNTY

A water sample from a shallow well near Twodot submitted to the Water Quality Bureau showed a moderate salinity (Table 8). The relationship to saline seep is unknown.

Table 8 -- County Groundwater Data

Location	Date Sampled	Well Depth	S.C.	Dissolved Solids	SAR	CA	MG	NA	K	CO_3	HCO_3	CL	SO_4	NO_3	pH	Source
Dawson 14N54E28DD	10-11-50	16.5	4550	3780		200	102	910	9.2		1070	35	1970	2.9	7.3	Moulder, Torrey, Koopman (1953)
13N53E 11DA	10-48	seep	5410	4900		305	470	547			376	94	3140	115	8.0	Torrey and Swenson (1951)
Glacier 34N7E 36DAA	8-2-56	9.5	2220	1500	8.0	24	86	376	.8	24	568	99	538	6.7	8.4	Paulson and Zimmerman (1965)
35N03N35CD		67.8		6760								24	4960			Zimmerman (1967)
Bighorn 03S33E8BD		28	7520	7240		428	273	1290	19	0	493	111	4400	13	7.1	Hamilton & Paulson(1968)
05S32E11BB		35	6030	5850		458	282	775	14	0	430	65	3450	122	7.1	"
Carbon 21N02E31	5-13-73		6400	5682	20.5	220	81	1400		0	770	10	3200	0.23	8.3	WQB
20N02E24AC	5-16-73		6200	7150	12.5	380	320	1370		0	495	72	4451	63.2	8.3	WQB

Table 8 -- County Groundwater Data (cont)

Location	Date Sampled	Well Depth	S.C.	Dissolved Solids	SAR	CA	MG	NA	K	CO_3	HCO_3	CL	SO_4	NO_3	pH	Source
Fallon 07N59E 36C	8-26-74		3570	3144	29.2	37	19.4	880		35	1399	7.5	767		8.4	WQB
09N57E 06DA	8-13-74		2840	2333	11.4	44	78	540		27	640	9.4	983	12.2	8.6	WQB
06N59E 11BC	8-7-73		2930	2456	70.7	6.3	1.0	727		80	1065	4.3	570	2.5	9.1	WQB
Garfield 19N35E10	6-74		5700	4622	49.8	39	11.8	1380			1027	8.1	2150	3.6	8.1	WQB
18N40E01C		65	4550	3630				1170		0	1090	18	1300		7.7	Van Lewen and King(1971)
23N41E25D		80	2380	2110				552		18	1100		408		8.0	"
Golden Valley 07N22E26DD	7-31-56		4620		77	11	2.3	1800	2.5	12	860		1600	4.2	8.2	Zimmerman (1956)
07N22E26DD	4-28-75		5600			1.1		1450					1120	1.4	8.16	WQB
06N22E02CA	7-30-56	39.4	13,900	14,100	20	296	677	2790	4.0	0	620	102	8890	4.0	7.9	Zimmerman (1956)
Hill 35N06E36AC	8-30-74		942		1.1	101	39	50		0	244	5.0	298	8.0	7.9	WQB

Table 8 -- County Groundwater Data (cont)

Location	Date Sampled	Well Depth	S.C.	Dissolved Solids	SAR	CA	MG	NA	K	CO_3	HCO_3	CL	SO_4	NO_3	pH	Source
Liberty 33N05E25	8-10-73		2410	2185	63.7	6.4	1.2	670		48	640	27	792	0.09	8.9	WQ8
Phillips 25N09E128D	4-24-74	18	4830	4319	4.5	525	194	480		0		0.1	2707	0.7	7.2	WQB
Sheridan 35N56E32	5-10-74	250	2083	1664	52.2	4.8	1.0	480		10	694	0.1	471	2.6	8.6	WQ8
35N38E22			3521			330	350	200		0	440	26	2160			WQB
Valley 37N42E12	12-17-73	50												270		WQB
37N42E12	12-17-73	78												100		WQ8
Wheatland 07N13E19B8	7-18-74	45	3332	2782	32.8	2.7	30	865		158	294	1.5	1430	0.0	9.82	WQB

IX. BIOLOGICAL ASSESSMENTS, LAKES, PONDS, STREAMS

Many prairie ponds, lakes, and reservoirs provide waters for livestock and wildlife; they are also used for fishing, recreation, and waterfowl habitat. Losing these ponds to salinity would end a valuable and much needed water resource. Degradation of many water bodies has already begun as the following indicates. Reports of "dead" trout ponds have been received from Valley, McCone, Daniels, Judith Basin, and Chouteau Counties. Deer deaths have been reported from Garfield and Judith Basin Counties. Undoubtedly, there are many such instances that are not reported. Harlow (1974) discussed biological impacts of salinity on wildlife, domestic animals, and crops in some detail.

Limiting concentrations of dissolved solids for fresh-water fish are not definitely known, but may range from 5,000-10,000 mg/1 (CWQC, 1963). Fish may become slowly acclimatized to higher salinities but sudden exposure to high salinities, such as those resulting from discharges of oil well brines (CWQC, 1963) result in death.

Nitrates are consistently identified from saline seep ponds; its toxicity to livestock and deer has been previously discussed. Nitrates have also proven toxic to young ducks (CWQC, 1963). The possibility exists that nitrate concentrations cause the loss of many prairie ponds as viable duck rearing locations.

Many saline area ponds contain nitrate concentrations conducive to toxic algal blooms. Sudden decomposition of these blooms has resulted in mass fish mortalities; similar observations were made in regard to livestock poisonings (Water Quality Criteria, 1973). These toxic algae are listed as Nodularis spumigena, Mycrocystic aeruginosa, Coelosphaerium kuetzingianum, Gloetrichia echinulata, Anabaena flos-aquae, and Aphanizomenon flos-aquae. These algae produce toxin that has known lethal capabilities. Nitrate concentration (in surface waters) by itself may not be harmful, but the algal bloom and resultant toxin will be fatal. Examination of waters for these species of algae is an important factor in saline water work. As the toxin is difficult to isolate, it is recommended that waters bearing heavy growths of blue-green algae be avoided.

Studies by Zeitoun (1973) (1974 A, B) concluded that increased salinities caused increased protein demands by rainbow trout, growth potential decreased, influenced metabolic rate, and caused loss of water from bloom cells. Similar results were obtained by Winberg (1956). Bayly (1966) suggests fauna colonization in saline ponds is limited, thus reducing necessary fish food. Toxicity to fish caused by saline seep constituents is as varied as are the toxicants; which may have proved toxic at various concentrations. A complete literature review is provided by Tomlinson (1974).

The most studied saline seep ponds are in the Highwood Bench area. Currently, Miller is conducting extensive hydrogeological work in this area. Four of five ponds in this area no longer support trout, the causes have yet to be determined. Complete chemical profiles of these ponds were conducted by National Field Investigations Center, Cincinnati, EPA. Results from this study indicated no abnormal chemical concentrations. This indicates the fish mortalities in these saline seep affected ponds is related in a complex manner to salinity and is not a direct effect of any one chemical constituent.

Chemical analyses were conducted from ponds, lakes, and reservoirs in Daniels, Fallon, Hill, Phillips, Sheridan, Stillwater, Sweet Grass, Toole, Valley, Wibaux, and Yellowstone Counties (Table 6). Water quality from standing water was variable. Some waters would support a fishery and be adequate for livestock usage. Three sites in Stillwater County (Table 6) would not support any freshwater fish. The specific conductances in these ponds ranged from 33,400 to 50,800 mhos/cm. A calculated dissolved solids value of 161,193 mg/l (Table 6) was recorded from a pond in Toole County. It is doubtful that this pond could support viable aquatic life or have any other beneficial use.

Chemical assessments of these ponds is as varied as their locations. The lakes analyzed from Sheridan County (Table 6) are reported to be naturally saline as are some of the ponds in Stillwater County. Water quality from other ponds, or lakes, is affected by their proximity to saline seeps, i.e., Stillwater, Valley, and Sweet Grass. Reservoirs and associated canals are not always affected by saline waters; however, salinity problems generally affect surrounding lands. Deadman's Basin (Wheatland County) and Glasten Reservoir (Sweet Grass County) are examples of excessive waters seeping through alkali soils. This seepage water is often salt-laden and is destructive to soil productivity, water quality, and aquatic life.

Examination of aquatic flora from various streams has led to the identification of various "salt-loving" forms. These diatoms were previously thought to exist only in arid regions of the southwest. These diatoms may provide an early warning system for streams which are undergoing salinity changes. A more complete description is provided in WATER INVENTORY OF THE MIDDLE MISSOURI BASIN (Kaiser, 1975).

X. FUTURE NEEDS

Salinity in Montana is causing significant economic and environmental problems. It is expected that future use of land and water resources will be more intense and it is expected that without careful land and water management, salinity problems will continually grow. Protection of Montana's soil and water resources from degradation due to improper management is very important to future generations.

A state-wide strategy must be developed and implemented to insure that salinity will not cause an increasing economic burden on the state's landowners and irreversible environmental damage. This strategy should include the following: implementation of current research results and recommendations.

The Department of State Lands can protect state lands by encouraging that lands under their jurisdiction be retained or returned to permanent vegetation covers. This is especially important in areas where seeps are spreading and pose threats to water quality.

It is apparent that salinity problems are not disappearing nor are abatement programs a proven factor. Therefore, it may become necessary to adopt land use regulations for marginal and other lands unsuited for agricultural activities.

Additional detailed work needs to be completed to determine the scope and magnitude of salinity problems and appraise the potential future impact of salinity on the state's land and water resources. There is a clear need for a coordinated state policy with respect to salinity that will result in proper use of soil and water to conserve the resources for future generations. Much effort needs to be put into determination of efficiency of water use, impact of sprinkler irrigation and development of guidelines for avoiding practices that create salinity problems.

It may become necessary to subject proposed irrigation systems, or other water diversion projects, to a review system. This review should contain the following minimal information: soil pH, soil depth, soil permeability, nearness of marine shales, affected stream drainage, height of water table, and affected aquatic biology. If the review results indicate a potential salinity problem, the proposed irrigation system should be discouraged.

Grasslands are areas which need future investigation. During this investigation, it was observed that over-utilized grasslands show saline seep effects (e.g., Fergus County). It is not known if these seeps are natural or if over-utilization provides the necessary medium for saline seep development. The possibility exists that over-utilized grasslands under-utilize moisture; thus, resulting in saline seeps similar to dryland farming practices.

Considerable work is needed to define those management practices that do not cause saline problems and economic loss of valuable cropland. Land owners must have positive incentives to discontinue land

and water practices that result in saline damage. Use of public lands both federal and state should be directed toward long-term sustained productivity and not at short-term economic gains that may lead to irreversible salinity damage.

A state-wide monitoring system is needed to measure the impacts of salinity and to determine the impacts of changes in land and water use in the state. Such a monitoring system could rely extensively on existing water quality measuring programs. This monitoring program should include streams, standing water bodies, groundwater, and public water supplies.

Implementation of new federal drinking water standards (PL 93-523) (Federal Register #51, 1975) should provide the necessary vehicle for monitoring municipal water supplies. This program is especially important in areas currently reporting groundwater problems.

Industrial sources--oil and gas brines--should not be omitted from these surveillances. The multitude of unlined pits may pose a problem similar to poisoned groundwater of the Cimarron Terrace, Oklahoma. (Salt water in the Cimarron Terrace, Oklahoma, (EPA, 1975) originating from oil field brines contaminated a large groundwater terrace. It is estimated 100 years or more are required to flush salt from this terrace.) Another salinity problem which may not immediately manifest itself is the potential sodium leaching from coal spoil banks. It is hoped that reclamation projects will keep the latter a potential threat and not a reality.

A biological assessment program should also be developed. This program can delineate species composition changes and provide a warning system for saline water problems. The aquatic biota rapidly reflects environmental chemical changes. It is difficult for a chemical analysis to detect subtle changes that affect the aquatic biota.

A comprehensive program is needed that adequately defines and understands the economic and environmental impacts of salinity in the state.

Future and/or continuing saline groundwater and surface water problems can be expected from oil and gas operations, coal mining, and agriculture. As long as alkali soils exist and are not properly reclaimed or utilized, alkali leaching will be a problem to high quality waters.

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APPENDIX A

GLOSSARY

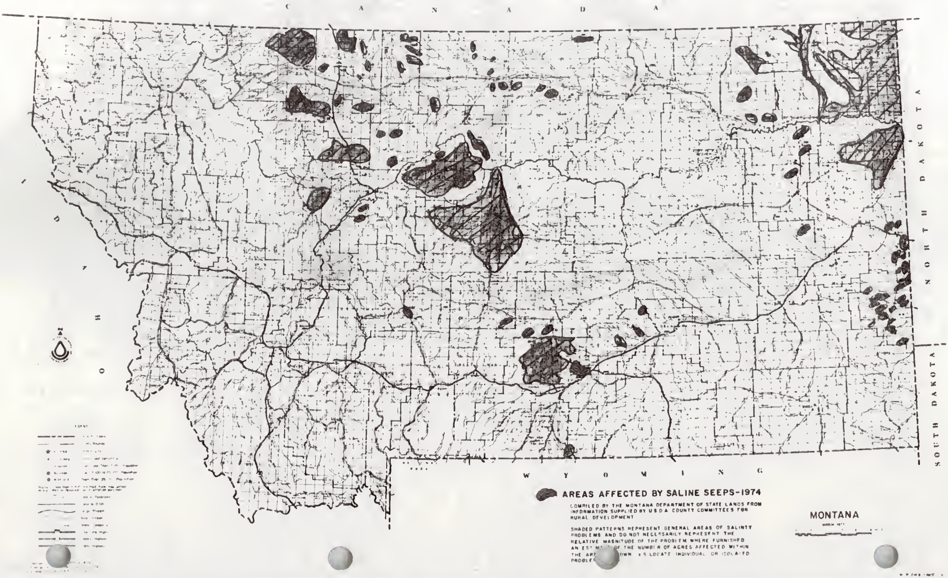
Symbol	Definition
BOD_5	Five-day biochemical demand
cfs	Cubic feet per second
gpcd	Gallons per capita per day
gpd	Gallons per day
gpm	Gallons per minute
JTU	Jackson turbidity unit
lbs/capita/day	Pounds per capita per day
lbs/day	Pounds per day
ml	Milliliter
mgd	Million gallons per day
mg/l	Milligrams per liter
sq. ft.	Square feet
TR	Total recoverable
tpd	Tons per day
μmhos	Micromhos per centimeter
$<$	Less than
$\leq$	Less than or equal to
$\geq$	Greater than or equal to
$\sim$	Approximately
BPT	Best practical treatment
WQB	Montana Department of Health & Environmental Sciences, Environmental Sciences Division, Water Quality Bureau
F & G	Fish and Game, Montana Department of
MPHES	Montana Department of Health & Environmental Sciences
MPDES	Montana Pollutant Discharge Elimination System
NPDES	National Pollutant Discharge Elimination System
BuRec	Bureau of Reclamation
EPA	U. S. Environmental Protection Agency
NOAA	National Oceanographic and Atmospheric Administration
SCS	U. S. Department of Agriculture, Soil Conservation Service
USGS	U. S. Geological Survey
USPHS	U. S. Public Health Service

APPENDIX B

U.S. DEPARTMENT OF AGRICULTURE

MONTANA

SOIL CONSERVATION SERVICE



AREAS AFFECTED BY SALINE SEEPS-1974

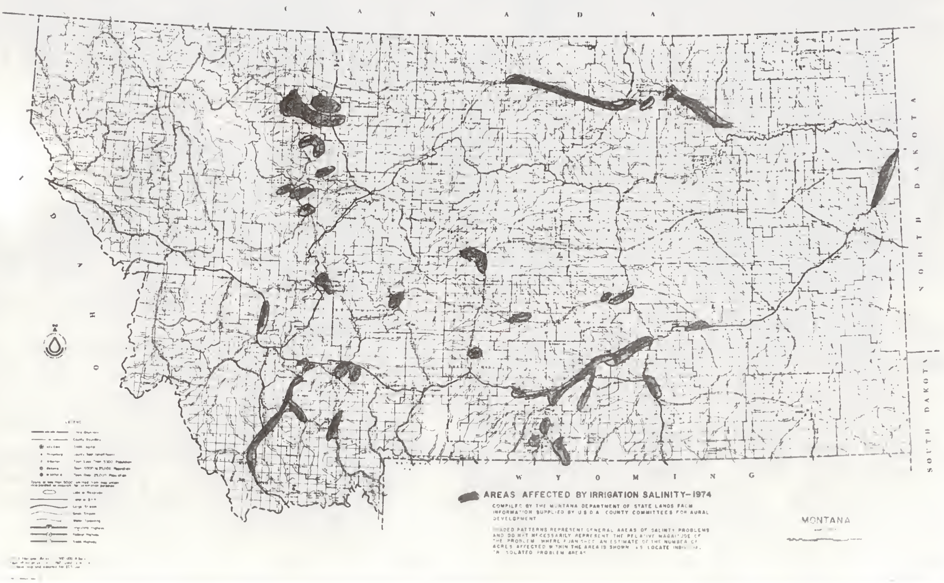
COMPILED BY THE MONTANA DEPARTMENT OF STATE LANDS FROM INFORMATION SUPPLIED BY U.S.D.A. COUNTY COMMITTEES FOR RURAL DEVELOPMENT

SHADED PATTERNS REPRESENT GENERAL AREAS OF SALINITY PROBLEMS AND DO NOT NECESSARILY REPRESENT THE RELATIVE MAGNITUDE OF THE PROBLEM. WHERE FURNISHED AN EST[illegible] OF THE NUMBER OF ACRES AFFECTED WITHIN THE AR[illegible]OWN. . . S LOCATE INDIVIDUAL OR ISOLATED PROBLE[illegible]

MONTANA

APPENDIX C

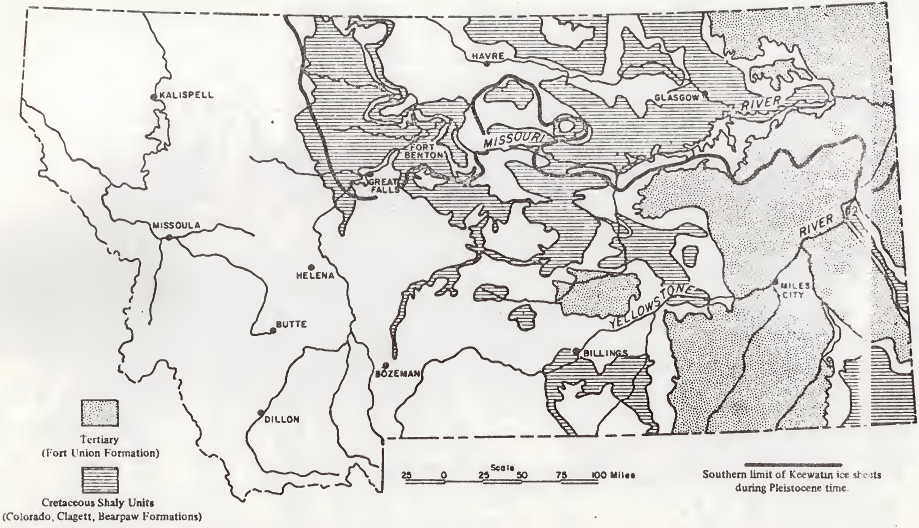
U.S. DEPARTMENT OF AGRICULTURE — MONTANA — SOIL CONSERVATION SERVICE



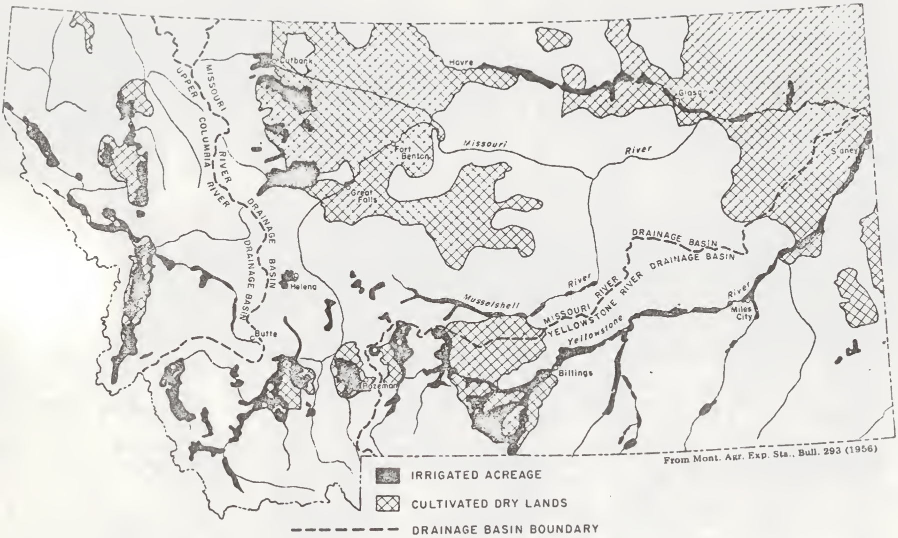
AREAS AFFECTED BY IRRIGATION SALINITY—1974

COMPILED BY THE MONTANA DEPARTMENT OF STATE LANDS FROM INFORMATION SUPPLIED BY U.S.D.A. COUNTY COMMITTEES FOR RURAL DEVELOPMENT

SHADED PATTERNS REPRESENT GENERAL AREAS OF SALINITY PROBLEMS AND DO NOT NECESSARILY REPRESENT THE RELATIVE MAGNITUDE OF THE PROBLEM. WHERE FURNISHED AN ESTIMATE OF THE NUMBER OF ACRES AFFECTED WITHIN THE AREA IS SHOWN. X'S LOCATE INDIVIDUAL OR ISOLATED PROBLEM AREAS.

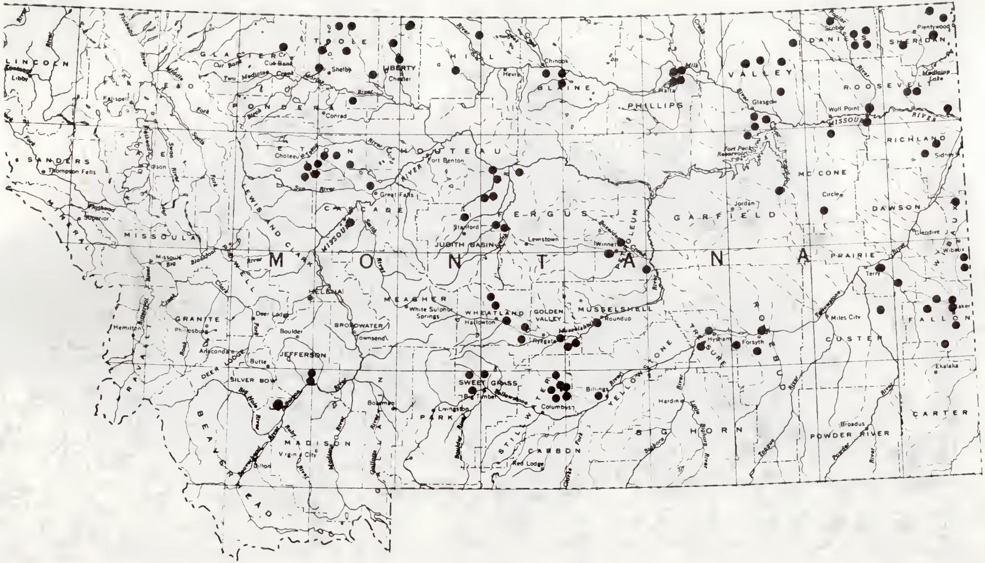

HAVRE
KALISPELL
GLASGOW
RIVER
MISSOURI
FORT BENTON
GREAT FALLS
MISSOULA
RIVER
HELENA
MILES CITY
YELLOWSTONE
BUTTE
BILLINGS
BOZEMAN
DILLON
Tertiary (Fort Union Formation)
Cretaceous Shaly Units (Colorado, Clagett, Bearpaw Formations)
Scale
25 0 25 50 75 100 Miles
Southern limit of Keewatin ice sheets during Pleistocene time.

Appendix D. Map of Montana showing areas underlain by thick shale units.

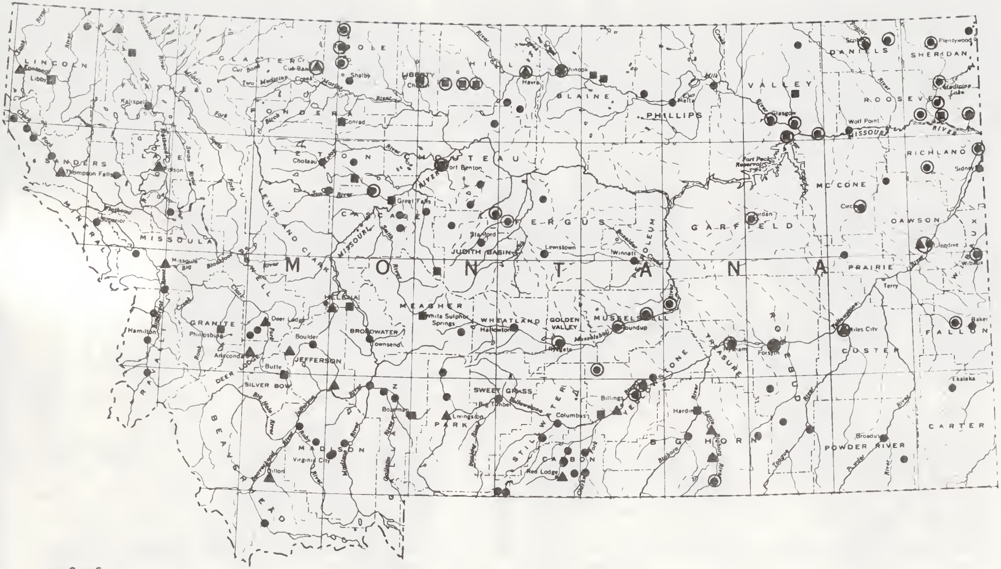


From Mont. Agr. Exp. Sta., Bull. 293 (1956)

Appendix E.—Cultivated land use in Montana



APPENDIX F. SAMPLING SITES



■ Surface

● Ground wells & springs

▲ Both

APPENDIX G MUNICIPAL WATER SUPPLIES

A larger circle around the above symbols indicates municipalities that are or could be affected by increased salinity.

ANNUAL REPORT

July 1, 1974 through June 30, 1975

FOUR-PROBE RESISTIVITY STUDY FOR MEASURING SOIL SALINITY

to

Department of State Lands
Helena, Montana

by

A. D. Halvorson and J. D. Rhoades
USDA, Agricultural Research Service

Northern Plains Soil and Water Research Center, Sidney, Montana
and
U. S. Salinity Laboratory, Riverside, California

FOUR-PROBE RESISTIVITY STUDY FOR MEASURING SOIL SALINITY

A. Project Objectives:

The general objectives of the project are: (a) to correlate field apparent soil conductivity (EC_a) values with saturation extract soil conductivity (EC_{se}) values (standard method of determining soil salinity) for one major soil type in six geographic areas of Montana; (b) to determine the influence of soil texture and water content on EC_a readings and interpretations; (c) to evaluate and demonstrate the 4-probe resistivity technique for mapping and monitoring surface and root zone soil salinity in the field, and to delineate surface and subsurface boundaries of seeps or potential seeps; (d) to develop typical EC_a vs electrode spacing curves for seeps, seep fringe, and recharge areas, and determine if the 4-probe technique can be used to delineate water table and permeable and impermeable strata in the geologic profile for the geographic areas mentioned; (e) to develop a field manual for use with the 4-probe resistivity equipment with instructions on how to operate the equipment and interpret data collected; and (f) to conduct training sessions at Sidney and Great Falls on the use of the 4-probe method of measuring soil salinity for service personnel and other state and federal agencies.

B. Project Activities - July 1, 1974 to June 30, 1975

Efforts made through June 30, 1975, to accomplish the objectives are as follows:

1. A total of six locations have been worked on for calibrating and correlating field salinity readings (EC_a) with the standard laboratory procedure for determining soil salinity (EC_{se}). Locations worked on include Scobey, Sidney, Molt, Conrad (2 sites), Highwood Bench, and Glasgow.

2. A total of 1345 field soil salinity readings were made at the above locations, 116 soil cores and deep test holes were drilled with 5 test wells established, and 594 soil samples collected for laboratory analyses. Each soil sample taken was analyzed for water content, soil salinity (EC_{se}), saturation percentage, calcium, magnesium, sodium, and testure. Data to develop typical EC_a vs electrode spacing curves has been collected for the Molt, Conrad, Highwood Bench, Glasgow, and Sidney locations.

3. A small hand-held seismic instrument, provided by the U. S. Salinity Laboratory, was used at the Molt, Conrad, and Sidney locations in an attempt to identify the type of geologic substrata (i.e. glacial till, shale, dense clay). Some difficulty was encountered with erratic

readings and data interpretation. However, preliminary results indicate that the seismic equipment may work quite well in conjunction with the 4-probe equipment for determining depth to and type of substrata. Use of the seismic equipment warrants further evaluation.

4. We have started to work on objective (b) and will be using a laboratory technique to evaluate the influence of texture and soil water on 4-probe salinity readings and interpretations.

5. Objective (c) has been completed and a technical manuscript has been prepared and is presently being reviewed. The title of the manuscript is "Field Mapping Surface and Subsurface Salinity in Dryland Soils" by A. D. Halvorson and J. D. Rhoades.

6. A technical manuscript has been prepared and is being reviewed on the use of a resistivity meter and fabricated conductivity cell for estimating the salinity of water samples. The title is "Estimating Water Salinity with Earth Resistivity Equipment" by A. D. Halvorson and C. A. Reule.

7. A technical manuscript is being prepared on the use of 4-probe conductivity cells for making salinity calibration curves. The title of the manuscript is "A Technique for Establishing Precise 4-Probe Electrical Conductivity - Soil Salinity Calibrations" by J. D. Rhoades, A. D. Halvorson, and M. T. Kaddah.

8. A workshop was held in May at Sidney to aquaint personnel from state and federal agencies on the use and operation of the 4-probe equipment.

C. Summary of results and conclusions to date:

1. The 4-probe technique can be used to map soil salinity in the field without recourse to soil sampling and laboratory analyses. The technique can be used to delineate surface and subsurface boundaries of existing, newly developed, or suspected seep sites.

2. Regression equations relating field soil salinity (EC_a) to laboratory soil salinity (EC_{se}) are available for five locations as follows:

Location	Regression Equation	Correlation Coefficient
Scobey	$EC_{se} = 4.53(EC_a) - 0.45$	0.996
Sidney	$EC_{se} = 4.84(EC_a) - 0.07$	0.960
Molt	$EC_{se} = 3.52(EC_a) + 0.91$	0.961
Conrad (Anderson)	$EC_{se} = 5.61(EC_a) - 0.64$	0.964
Conrad (Mokma)	$EC_{se} = 5.23(EC_a) + 0.13$	0.979
Highwood Bench	$EC_{se} = 6.50(EC_a) - 0.21$	0.969

Even without these regression equations, the 4-probe technique could be used to determine whether or not a possible soil salinity problem exists at a site in question. A field salinity reading in a non-salt affected area compared to the salinity reading taken in the questionable area should be sufficient to tell if a possible salt problem exists. The regression equations are needed however, to convert to standard soil salinity values (EC_{se}).

3. The 4-probe workshop held at Sidney was well received and attended. There were a total of 32 participants from Bureau of Land Management, Bureau of Reclamation, Agricultural Research Service, Montana State University, North Dakota State University, South Dakota State University, Extension Service, Soil Conservation Service, Montana Bureau of Mining and Geology, Montana Department of Agriculture, Montana Department of State Lands, Montana Water Quality Bureau, and Montana Department of Natural Resources. Quoting from Wendell Thacker's report on the workshop to State Conservationist Mr. Van K. Haderlie, he said, " It appears the 4-probe system can be a highly useful tool for the Soil Conservation Service."

D. Difficulties encountered in fulfilling the project objectives:

It was difficult to schedule and carry out field work because of inclement weather.

E. Future Plans:

We plan to complete the field and laboratory work for each of the objectives by June of 1976. We plan to conduct another 4-probe workshop in the Great Falls area in April or May of 1976. We plan to have the 4-probe field manual available by December 1976 as scheduled.

F. Summary of Project Expenditures for Fiscal Year 1975:

Personnel Services	$ 6724.83
Capital Equipment	3452.00
Operating Expenses	7204.14
Total Expenditures	$17,380.97

Because of a delay in receiving the funding in July 1974 and finding a field and laboratory aid, not all of the money budgeted for personnel services was used in FY 1975. However, the money will carry over into FY 1976 and will be used as planned. The same was true for the operating expenses, some travel was canceled or cut short because of inclement weather conditions but will be used in FY 1976.

SALINE CONTROL PROJECT

JOHN G. DUKE
P. O. Box 427 Ph. 357 2310
CHINOOK, MONTANA 59523

Saline Control Project

Progress Report

From

Jan. 1 to June 30, 1975

Introduction

The first thing was to get acquainted with the Paradise Irrigation District and its problems. Lee Jones gave me all the material on the Paradise District that he had in the office, Working Agreement; Reconnaissance Report on Water Control, Use and Disposal; Survey Report on Drainage; Analysis and Interpretation of Climatic Data; Reconnaissance Report outlining Drainage Problems and Investigations in the Paradise Valley Irrigation District. These gave a short history of the problems from 1946 up to the present time. The problems haven't changed much in the last 30 years.

Adequate drainage is the greatest single need of the District. Even with drainage provided, the predominating flat and heavy clay soils in the district present a particular problem in land preparation and farm irrigation practices. They lie nearly level with very poor surface and very slow internal drainage, therefore irrigation is difficult and surface ponding make ideal mosquito hatches. These lands need to be leveled and build more grade into them so that water will drain off. All of these heavy clay soils has some alkali in them.

Surface drainage is poor throughout the District. Glacial mounds and ridges tend to restrict drainage. Irrigation ditches in many instances obstruct surface drainage.

In general, the area lends itself to considerable flexibility in irrigation requirement. Full production with maximum yield may require five irrigations in the dry years and only three in the wet years.

Seepage from canals is obviously a contributing factor to the present high water table. Determination of this loss on sections of the main canal might indicate the advisability of lining. Many sections of the main canal and laterals are necessarily built on fills and these sections seep badly.

Much of the irrigated land in the Paradise District is fairly well developed, although there are probably few farms on which land use could not be improved by better land preparation and better farm irrigation facilities. Lack of primary surface drainage has prevented or discouraged intensive development in many cases, especially on the flat lands with heavy clay soils.

Objectives

1. Determine the cause of decline and loss of soil productivity.
2. Investigate means of reclaiming seeped and saline soils.
3. Develop guideline and plan for improving crop production in the District.
4. Develop plan for mosquito abatement.

Efforts made to Accomplish Objectives

I familiarized myself with the soils I would be working on. I questioned the classification of some soils. After field checking with Huey Long, Soil Scientist, some changes were made in the classification.

In December I took 27 soil samples from several soils at various depths and sent them to Bozeman for testing. Results showed some soils had higher salt concentrations than predicted. Some of the profiles showed that the salts had been leached down to about the 30 inch depth. Other profiles showed the salt was moving up to the surface.

I took water samples from the exploratory wells in September and January and sent them to Bozeman for testing. All the tests showed that the water was high or very high in salts.

I went over the District mapping the location of ditches and drains. This way I was able to contact most of the operators in the District and talk to them about their problems and any solution they might have.

Last fall I finished making a structure inventory of the District canals that had been started but never completed. There are 142 turnouts, 40 checks, one diversion dam, one inlet structure, and 12 other structures in the canal system that require maintanence.

During the winter I made overlays showing the canal system, (31 miles); drainage system, (86 miles); saline soils, (47% of area); Wildlife Habitat, (2530 acres); ownership map, (53 operators); and canal sections that seep.

I made a tracing of Paradise Valley from a one foot contour topography map made by the Bureau of Reclamation for the Milk River project.

I have written two articles for the Blaine County Soil Conservation District Newsletter that is published quarterly.

I have one location for a closed drain but have not been able to get the contractor to put it in yet. Also one grass planting trial started.

Last March I gave a talk to the Blaine County Committee for Rural Development (CRD) meeting. We had a good discussion on the Saline Control Work that I am doing. I presented the same talk to the four-county Milk River CRD in Malta on March 13, 1975. Representatives from all irrigation districts in Blaine, Phillips and Valley counties also attended. The group was very interested in one comparison chart I made of the water levels of the 1947 and 1974 well readings. This comparison chart shows that all the drainage laterals (86 miles) that have been installed since 1947 have not lowered the water table much, if any. The chart is included with this report.

Preliminary Conclusions

On April 7, 1975 we had a big snow storm that gave us 22 inches of snow. When the snow melted off the following week I kept a daily check on the river. It came up about 5.5 feet. Then on May 5, 1975 when I read the observation wells they had come up from .7 to 5.9 feet. Most of them made about a 3.0 foot rise from the snow melt.

When the water was turned into the canals and laterals one well took a big jump. Well #9 is 65 feet from the lateral and the first day (24 hours) the water table came up 1.8 feet. In one week the water table raised 4.1 feet to one inch above ground elevation. The ground was covered with one inch of water that came up from underneath. In one week after the water was shut off the well dropped 2.4 feet. This is evidence that the water moves quite rapidly in the subsurface strata.

Since then I have been watching the laterals when water is turned into them. The barrow pits along the side of the ditch soon fill up with water or they soak out into the field. About one day and you can see evidence of water coming through the ditch bank.

One reason for over-irrigating is some runs are too long and/or the borders are too wide for the soil and slope of the field. It takes too long to push the water through to the end of the run with the result that too much water leaches down to the water table taking fertilizer and plant nutrients with it. If the runs were shorter, the borders narrower, or a bigger head of water was used these lengths could be all right.

Exchangeable sodium exerts a two fold effect in promoting a poor physical condition of the soil, and in bringing about an unbalanced nutrition of plants. Soils with high exchangeable sodium are readily deflocculated and they puddle readily at low moisture contents.

Because salts move with water, salinity depends on water management, that is irrigation, leaching and drainage. These three aspects of water management should be considered collectively in the overall plan for an irrigated area.

Management is one way, and the most important, that these soils will be reclaimed and put back into production. Manage the water that is used for irrigation and use only what the crop can use. Use the cropping system that will be the most benefit to the soil while making a living for the land operator. Return all crop residue and all manure to the soil to build up the organic matter and humus.

Difficulties Encountered

I haven't had any difficulties in getting permission to get on to farmer places.

The only difficulties that I have encountered is in getting practices installed.

Future Plans

I have the infiltration rings and plans to make some studies on the important soils in the valley.

I have two Parshell Flumes but they have not been installed yet. There is some laterals that I would like to measure the water into and when it gets to its destination to check the loss from seepage. 1976 will be the implementation phase for this study.

Specifically proposed projects will include:

1. Ditch Sealing (bentonite or plastic)
2. Salt tolerant grass trials
3. Application of manure and/or organic matter
4. More drains
5. Drain ditches with side slopes 3:1 or more (to prevent sloughing)
6. Sump pumps to permit steeper grades on drains
7. Proper water application.
8. Installing weirs and parshell flumes for water management
9. Deliniate areas of greatest problems for study priorities

I plan to attend other Irrigation District Board meetings to explain project progress and solutions found, as it relates to their areas.

A booklet will be published at the end of the study outlining the problems and the best solutions found in preventing and reclaiming saline soils.

Expenditures

Salary and benefits	$9856.00
Pickup	525.35
Travel expenses	140.51
Testing	911.75
Equipment	781.21
Misc. expenses	246.03

Submitted by:
John G Duke
John G. Duke
Drainage Specialist

If the wells are located fairly accurately on the 1946 map then the 1946 and 1974 wells are close enough for comparisons. Most of the 1946 wells have long ago been lost. (1946 well 25 is still in service. The only one. I am reading it monthly along with 1974 wells.)

Drain ditches have been constructed in all areas of the District with varing degrees of success. The land generally slopes from the river to the foothills. This means any drain ditches starting near the outer edge of the valley floor is relatively shallow to allow draining to the river. The relatively flat grade of the valley (average 2.5 ft. per mile between Chinook and Harlem) make it difficult to get enough slope to keep the drains running freely or deep enough to lower the water table.

The red is the highest water reading usually from June to September during the irrigation season. The blue the lowest reading about March.

Well 2 (1974) is 10 feet from the drain berm. The drain is 3.8 feet deep. The high water elevation in the well is about .5 feet above the drain. The well is between the source of the ground water and the drain.

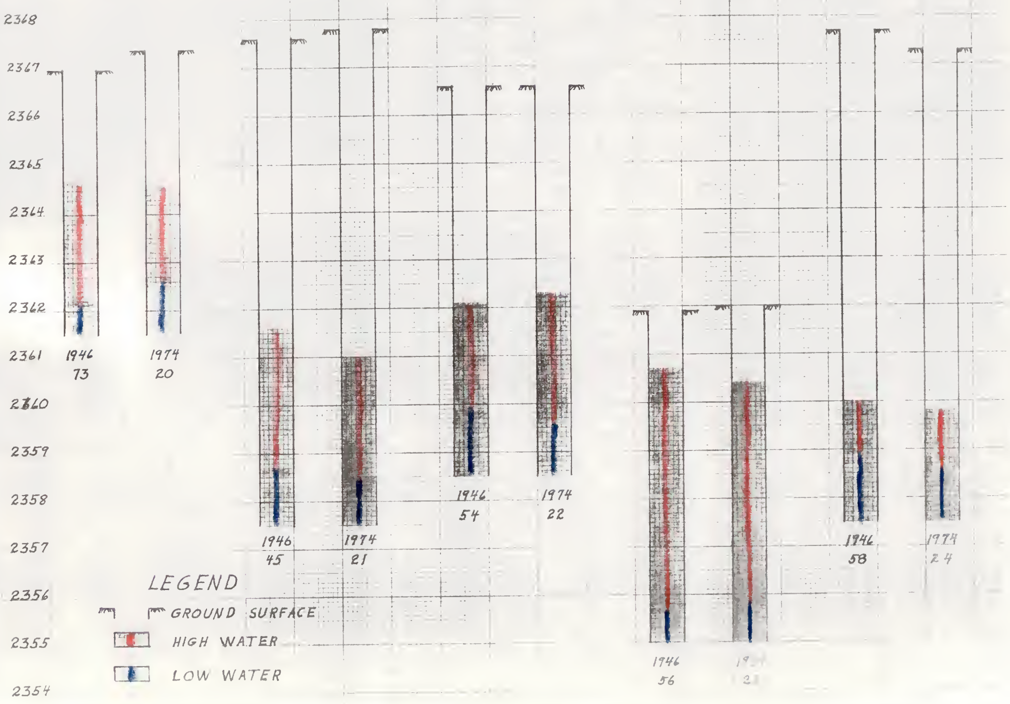
Wells 13 and 8 are close to the Hillside Ditch which accounts for the large flocculation in the water levels.

Well 14 the water in the casing was above ground. Enough pressure to push the water .3 foot above ground.

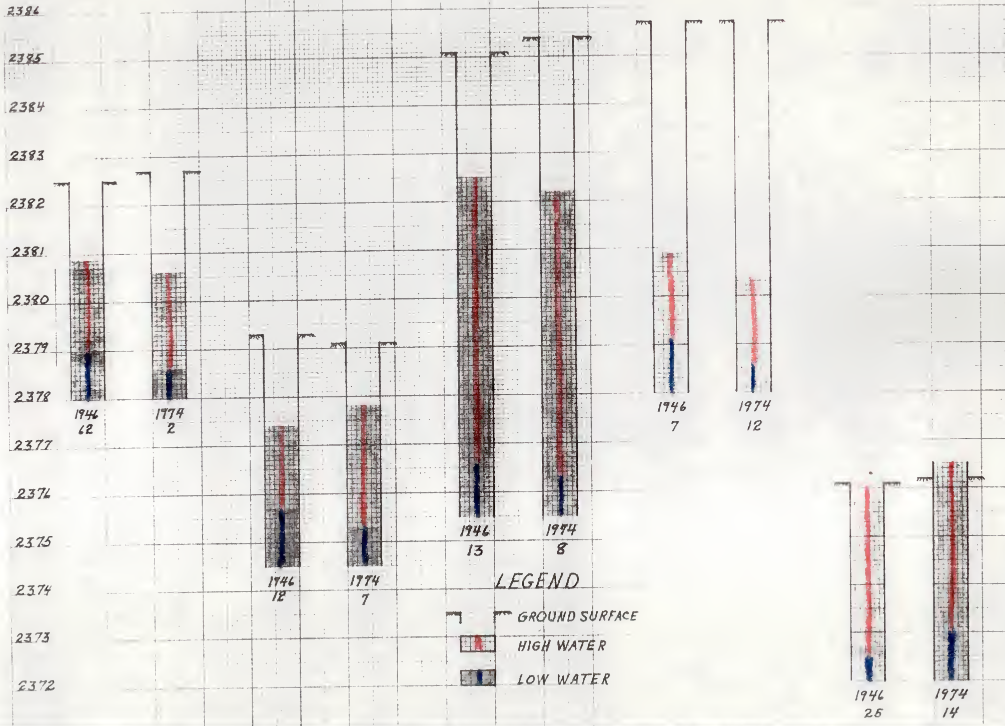
Wells 56 and 23 shows a big flocculation in water level. Water levels are a result of irrigation. There is a shallow road barrow pit about 3 feet from the well that is used to drain off excess irrigation water.

Well 24 is about 330 feet from the canal but it don't seem to influence the water level in the well. In April and May when we had a lot of snow and rain the other wells showed increases but well 24 did not.

1946 & 1974 WELL COMPARISONS



1946/1974 WELL COMPARISONS



ANNUAL REPORT
F.Y. 1975
TO
OLD WEST REGIONAL COMMISSION

Submitted by

Soil & Water Conservation Districts of Montana, Inc.

The following is a summary of the activities during fiscal year 1975 (February 1 through June 30, 1975). Detailed information can be found in the individual reports for the 3rd and 4th quarters.

An extensive literature review was conducted to determine those species adapted to the region's climatological and environmental conditions with proven or suspected tolerance of salty soils and/or a high water table. Seed of such plant materials was requested from numerous SCS Plant Materials Centers as well as universities and the USDA Agricultural Research Service. A total of 247 accessions have been assembled. Each accession was tested for percent germination before being seeded in both a saline (Treatment) and nonsaline (Control) site. Records are being kept of seedling emergence and soil conditions.

A Bermuda King sprig planter is being tested for planting root material of various rhizomatous grasses and legumes. Five of these plant accessions are available for such use at the Bridger PMC. A number of soil amendments, fertilizers, and root growth hormones have been acquired to try to stimulate vegetative reproduction of rhizomatous plant materials.

Collections of inland saltgrass were requested from select SCS field offices in Montana and Wyoming. The root materials were planted in moderately salty soils and will be evaluated for their vigor and spreading ability. Eighteen accessions of wildrye have been received from the USDA-ARS in Logan, Utah. These seeds have been planted in good soil and will be grown for seed.

A request for seed collection has been sent out to all SCS field offices. This request includes plant materials that will be found growing on harsh salty sites throughout Montana and Wyoming. This seed collection will be supplemented by seed collected by the PMC staff on special seed collection trips.

Through the cooperative agreements between SWCDMI and SCS, special equipment has been made available for use on the saline seep project. Persons working on saline seeps have access to the following equipment: Bermuda King sprig planter, Ford 3000 with dual wheels, flat-bed trailer and pickup truck, drill seeder, and miscellaneous farm equipment.

An unusually wet and cold spring delayed all seeding and planting activities at least one month, but as of the end of fiscal year 1975 everything is on schedule as presented in the annual work plan.

DEPARTMENT OF STATE LANDS

PLANT MATERIAL CENTER

	1st Quarter Expense	2nd Quarter Expense	Total Expenses	Project Budget
Program Coordinator	200.00	150.00	350.00	350.00
Secretary	90.75	9.25	100.00	100.00
Travel	88.76	116.72	205.48	100.00
Per Diem	65.30	52.10	117.40	250.00
Indirect Costs	50.00	75.00	125.00	125.00
Cooperative Agreement with SCS	- 0 -	1,000.00	1,000.00	1,000.00
Plant Material Development	- 0 -	5,075.00	5,075.00	5,075.00
Totals	$494.81	$6,478.07	$6,972.88	$7,000.00

Balance carried over on continuing program - $27.12

QUARTERLY REPORT
TO
OLD WEST REGIONAL COMMISSION

Submitted By

Soil & Water Conservation Districts of Montana, Inc.

The activities of the period April 1 through June 30, 1975, are as follows:

1. Initial Evaluation Seeding Trials.

A total of 247 accessions (see appendix A) of perennial grasses, forbs, legumes, and shrubs were planted in individual 5-meter-long rows with 1-meter spacing. Five (5) grams of seed of each accession were planted with a hand belt seeder at a depth of approximately 1 centimeter. The entire initial evaluation seeding was replicated twice: one seeding in a natural saline seep (Field H), and the other in a well drained, non-saline site (Field 2).

On May 27, Field 2 (control site) was roto-tilled, harrowed, and floated. The majority of seed was planted on May 29, while late arriving seed from the National Plant Materials Center at Beltsville, Maryland, was seeded on June 10.

An attempt was made to harrow Field H (treatment site) with a tractor on June 3, but the soil was too wet. On June 4-6 the rows were hoed by hand to break up and dry the surface soil. All seeding was done on June 11. Inclement weather and poor field conditions prevented the seeding of both the treatment and control plots at the same time.

Relatively homogeneous sites were chosen based on results of analyses of soil samples collected earlier (see appendix B). The soils of the saline seep are strong to very strongly salty, so should be representative of the conditions of typical saline seeps in this region. Soils will be periodically checked for salts concentration and uniformity.

Records are being kept of seedling emergence and vigor. All accessions are checked weekly.

An irrigation ditch has been surveyed in Field H, which will provide irrigation water if needed. Field 2 will be irrigated with gated pipe.

2. Inland Saltgrass Collections.

Collections of inland saltgrass (*Distichlis stricta*) were requested from various SCS Field Offices in Montana and Wyoming. The Plant Materials Center at Los Lunas, New Mexico, also sent four accessions collected in Colorado. The requests asked that saltgrass rhizomes be removed from a relatively pure stand growing under wet-saline conditions. Rhizomes were to be collected from a 3-sq.-ft. area.

Each collection has been replanted in 1-1/2 X 1-1/2 meter plots with 1-1/4 meter spacing. A total of 13 collections have been received and planted to date.

3. Sprigging Trials.

A Bermuda King one-row sprigging machine has been purchased. Some rhizomes have been dug and run through the machine to calibrate the drive mechanisms and to learn the operating procedures. Five plant species are readily available for use in the sprigging trials: 'Rosana' western wheatgrass (*Agropyron smithii*), 'Critana' thickspike wheatgrass (*Agropyron dasystachyum*), 'Garrison' creeping foxtail (*Alopecurus arundinaceus*), beardless wildrye (*Elymus triticoides*), and 'Lutana' cicer milkvetch (*Astragalus cicer*). Strips of each of these species have been mowed and are ready to be plowed up.

A variety of soil amendments and root growth hormones will be experimented with to stimulate vegetative reproduction of these plant materials. Various fertilizers, gypsum, gibberellic acid, Indole-butyric acid and napthenalacetic acid compounds have been acquired.

During the first week in July, a time-of-year study will be initiated in which sprigs will be planted the first of each month into late fall and beginning again in early spring 1976.

4. Miscellaneous Plant Requests.

Eighteen accessions of *Elymus* (appendix C) have been received from ARS plant geneticists at Logan, Utah. These accessions are a result of an extensive breeding and selection program of wildryes to determine tolerance of saline-alkaline conditions. Only small amounts of seed were received. This seed has been planted in the control plot (Field 2) and not in the saline seep plots. Once an adequate seed supply has been developed, these accessions will be tested under wet-saline conditions.

A request for seed collection has been sent out to SCS Field Offices in Montana and Wyoming. The listed species (appendix D) will be harvested as they mature throughout the summer months. This seed supply will be supplemented by seed collected by the Plant Materials Center staff on special seed collection trips.

Cuttings of accessions of Siberian salttree (*Halimodendron halodendron*) and Tamarisk (*Tamarix hispida*, *Tamarix pentandra*, and *Tamarix tetrandra*) have been received from the ARS nursery in Cheyenne, Wyoming. These cuttings have been planted in small flats to root and develop before being replanted in the saline soils.

5. Soil Sampling and Analyses.

A portable Solu-Bridge has been acquired for measuring the salts conductivity of saline soils. All necessary glassware has been acquired to develop a small soil testing laboratory. Soils in the test plots will be monitored for salts concentration and uniformity. When native seed is collected the soils will be tested to determine the harshness of each site.

APPENDIX A. Plant species seeded in initial evaluation trials.

Scientific Name	Accession	Year	Origin
Agropyron cristatum	CR-3	72	Nampa, Idaho
" "	Fairway	72	Canada
Agropyron dasystachyum	Critana	72	Bridger PMC
" "	M-449	62	Plentywood, Montana
" "	P-1822	68	Pullman PMC
Agropyron elongatum	Alkar	69	Bridger PMC
" "	Jose	72	Los Lunas PMC
" "	Largo	68	Los Lunas PMC
" "	Orbit	74	Canada via MSU
" "	PI-297871		Beltsville, Maryland
" "	PI-315352		Beltsville, Maryland
" "	PI-358362		Beltsville, Maryland
" "	PI-368851		Beltsville, Maryland
" "	BN-20469-73		Beltsville, Maryland
Agropyron inerme	Whitmar	66	Pullman PMC
Agropyron intermedium	A-12496	68	Los Lunas PMC
" "	Amur	70	Los Lunas PMC
" "	Greenar	70	Bridger PMC
" "	Tegmar		Aberdeen PMC
Agropyron riparium	Sodar	74	Aberdeen PMC
" "	WY-306	62	Bridger PMC
Agropyron sibiricum	A-10675	65	Aberdeen PMC
" "	P-27	69	Aberdeen PMC
Agropyron smithii	Barton	70	Manhattan, Kansas
" "	Mandan-456	64	Bismarck PMC
" "	P-727	63	Pullman PMC
" """	Rosana	74	Bridger PMC
Agropyron trachycaulum	Revenue	71	Saskatoon, Saskatchewan
Agropyron trichophorum	Luna	72	Pullman PMC
" "	Mandan-759	73	Bismarck PMC
" "	Topar	71	Tetonia, Idaho
Agrostis alba	QS-04101	70	Northrup-King
Alopecurus arundinaceus	Garrison	72	Bridger PMC
" "	P-14762	64	Pullman PMC
Alopecurus pratense	P-5903	74	Pullman PMC
" "	P-15619	68	Pullman PMC
" "	Rhoena	72	Forest Grove, Oregon
Andropogon gerardi	NDG-4	66	Bismarck PMC
" "	SD-27	66	Bismarck PMC
Andropogon hallii	M-241	71	Bridger PMC
" "	ND-265	62	Bismarck PMC
Andropogon scoparius	P-15584	68	Bridger PMC
Arrhenatherum elatius	Tualatin	68	OSU via Corvallis PMC
Beckmania syzigachne	M-285	60	Glasgow, Montana
" "	M-621	63	White Sulphur Springs, Mont.
Bouteloua curtipendula	M-118	62	Bridger PMC
" "	ND-89	59	Bridger PMC

Scientific Name	Accession	Year	Origin
Bromus biebersteinii	Regar	74	Aberdeen PMC
Bromus inermis	Carlton	70	Saskatchewan, Canada
" "	Lincoln	68	Northrup-King
" "	Magma	70	Saskatoon, Saskatchewan
" "	Manchar	73	Bridger PMC
" "	Mandan-404	65	Mandan, North Dakota
Bromus pumpellianus	P-15587	67	Bridger PMC
Bromus riparius	P-2336	63	Pullman PMC
Buchloe dactyloides	SB-045	72	Healy, Kansas
Calamovilfa longifolia	P-15588	73	Bridger PMC
Carex eleocharis	M-899	67	Bozeman, Montana
Dactylis glomerata	A-1801	69	Aberdeen PMC
" "	Chinook	64	Bridger PMC
" "	Frode	70	Ontario, Canada
" "	Latar	66	Bridger PMC
" "	Pomar	71	Aberdeen PMC
Danthonia parryi	WY-381	63	Laramie, Wyoming
Deschampsia caespitosa	M-255	67	Lethbridge, Alberta
Elymus angustus	Altai	67	Swift Current, Saskatchewan
" "	Mandan-1340	59	Mandan, North Dakota
Elymus cinereus	M-262	60	Whitehall, Montana
" "	M-382	61	Hot Springs, Montana
" "	P-15590	73	Bridger PMC
" "	P-5797	74	Aberdeen PMC
" "	WY-236	74	Kane, Wyoming
Elymus dahuricus	PI-314680		Beltsville, Maryland
Elymus giganteus	NB-328	73	Bridger PMC
" "	Volga	72	Pullman PMC
Elymus glaucus	P-2662	67	Pullman PMC
Elymus junceus	Mayak	71	Canada via MSU
" "	Mandan D-19	71	Mandan, North Dakota
" "	P-9012	69	Aberdeen PMC
" "	P-210	73	Pullman PMC
" "	Sawki	71	Canada via MSU
" "	PI-314665		Beltsville, Maryland
" "	PI-314675		Beltsville, Maryland
" "	PI-370672		Beltsville, Maryland
" "	BN-3010-64		Beltsville, Maryland
" "	BN-14844-63		Beltsville, Maryland
" "	BN-21994-71		Beltsville, Maryland
Elymus triticoides	P-15594	73	Bridger PMC
Festuca arizonica	Redondo	72	Los Lunas PMC
Festuca arundinacea	Alta	74	Pullman PMC
" "	Fawn	67	Corvallis PMC
" "	Goars	69	Pleasanton PMC
" "	Kenmont	71	MSU
" "	NM-384	68	Los Lunas PMC
" "	P-14944	71	Aberdeen PMC

APPENDIX A. (Continued)

Scientific Name	Accession	Year	Origin
Festuca elatior	Ensign	70	Ottawa, Canada
" "	Mimer	70	Ottawa, Canada
" "	Trader	70	Ottawa, Canada
Festuca ovina duriuscula	Durar	72	Pullman PMC
Festuca rubra	Clatsop	73	Corvallis PMC
" "	PI-371739		Canada via Alaska
Glyceria grandis	M-939	69	Sheridan, Montana
Hilaria jamesii	A-12413	72	Tucson PMC
Hordeum brachyantherum	WY-830	69	Bridger PMC
Lolium perenne	Caprice	72	Oregon
" "	Splendor	72	Oregon
Muhlenbergia montana	C-56	64	Bridger PMC
Muhlenbergia porteri	A-13273	71	Tucson PMC
Muhlenbergia wrightii	A-8604-67	67	Tucson PMC
Oryzopsis hymenoides	Paloma	74	Bridger PMC
" "	P-15597	66	Bridger PMC
Oryzopsis miliacea	PI-198091		Beltsville, Maryland
" "	PI-230621		Beltsville, Maryland
" "	PI-287909		Beltsville, Maryland
" "	BN-9142-61		Beltsville, Maryland
" "	BN-13702-61		Beltsville, Maryland
Panicum virgatum	A-6606	68	Los Lunas PMC
" "	C-10	66	Bridger PMC
" "	Neb-28	63	Lincoln, Nebraska
" "	P-15599	70	Bridger PMC
" "	Summer	68	Brookings, South Dakota
Phalaris arundinacea	Frontier	68	Corvallis PMC
" "	P-329	69	Pullman PMC
" "	P-15601	72	Bridger PMC
" "	P-2369	66	Pleasanton PMC
" "	Superior	68	Corvallis PMC
Phalaris canariensis	R-808	67	Northrup-King
Phleum pratense	Drummond	70	Corvallis PMC
" "	Dural	70	Winnipeg, Canada
" "	M-956	72	Philipsburg, Montana
Poa ampla	P-8903	63	Bridger PMC
" "	Sherman	70	Bridger PMC
Poa ampla x *pratensis*	P-14094	63	Pullman PMC
Poa bulbosa	P-4874	61	Pullman PMC
" "	WY-275	61	Thermopolis, Wyoming
Poa canbyi	WY-219	63	Sweetwater County, Wyoming
" "	WY-837	57	Independence Rock, Wyoming
Poa glaucantha	Draylar	69	Pullman PMC
Poa longifolia	A-10700	64	Bridger PMC
Poa nevadensis	M-1	63	Bridger PMC
Poa pratensis	Troy	74	Bridger PMC

APPENDIX A. (Continued)

Scientific Name	Accession	Year	Origin
Puccinellia airoides	CSU	73	Fort Collins, Colorado
" "	M-41	70	Bridger PMC
" "	M-45	60	Teton County, Montana
" "	M-692	64	Choteau, Montana
" "	M-917	67	Sanders County, Montana
Puccinellia distans	#666		Fort Collins, Colorado
Scirpus robustus	AB-369	66	Aberdeen PMC
" "	AB-535	71	California via Aberdeen
" "	Comm.		Corvallis PMC
Setaria italica	P-14981	68	Corvallis PMC
Setaria viridis	M-833	65	Bridger PMC
Sorghastrum nutans	Holt		Holt, Nebraska
" "	Osage	67	Manhattan, Kansas
Spartina pectinata	K-1099		Marshall County, Minnesota
" "	K-1100		Marshall County, Minnesota
" "	K-1101		Marshall County, Minnesota
" "	K-1105		Jones County, South Dakota
" "	K-1106		Faulk County, South Dakota
" "	K-1107		Tripp County, South Dakota
" "	K-1108		Eddy County, North Dakota
" "	K-1109		Kidder County, North Dakota
" "	K-1110		Towner County, North Dakota
" "	K-1111		Wells County, North Dakota
" "	K-1112		Hand County, South Dakota
" "	K-1113		Dewey County, South Dakota
" "	K-1114		Pierce County, North Dakota
" "	K-1119		Burleigh County, North Dakota
" "	K-1135		Kittson County, Minnesota
" "	K-1136		Kittson County, Minnesota
" "	K-1165		Polk County, Minnesota
" "	K-1167		Polk County, Minnesota
" "	K-1800		North Platte, Nebraska
Sporobolus airoides	M-21	72	Bridger PMC
" "	NM-184	69	Los Lunas PMC
" "	WY-51	60	Manderson, Wyoming
" "	WY-244	61	Worland, Wyoming
Sporobolus cryptandrus	M-898	66	Three Forks, Montana
Stipa comata	M-963	74	Bridger PMC
Stipa viridula	P-15604		Bridger PMC
" "	WY-218	65	Bridger PMC
Stipa x *oryzopsis*	NDG-771	67	Bridger PMC
Astragalus agrestis	NDL-3	57	Dickinson, North Dakota
Astragalus cicer	Lutana	73	Bridger PMC
" "	Oxley	72	Lethbridge, Alberta
" "	P-498	65	Bridger PMC

APPENDIX A. (Continued)

Scientific Name	Accession	Year	Origin
Astragalus falcatus	NDL-86	59	Mandan, North Dakota
Astragalus flexuosus	NDL-21	58	Bottineau, North Dakota
Astragalus galegiformis	M-955	72	MSU
Astragalus onobrychis	NDL-84	57	North Dakota
Astragalus semibicularis	NDL-87	55	North Dakota
Astragalus striatus	NDL-14	56	Jackson, South Dakota
Coronilla varia	Emerald	62	Elsberry, Missouri
Hedysarum boreale	WY-520	69	Jackson, Wyoming
Lathyrus ochroleaerus	NDL-34	51	Bottineau, North Dakota
Lathyrus latifolius	P-15660	73	Corvallis PMC
Lathyrus tingitanus	M-290	61	Bridger PMC
Lathyrus tuberosus	M-351	61	Granite County, Montana
Lliamna grandiflora	NM-529	68	Los Lunas PMC
Lotus corniculatus	Tana	58	Huntley, Montana
Medicago falcata	P-13333		Pullman PMC
" "	Travois	65	South Dakota
Medicago sativa	Ladak 65	70	Beltsville, Maryland
" "	Methow	70	Pullman PMC
" "	Ranger	61	Forsyth, Montana
" "	Teton	70	Brookings, South Dakota
" "	Vernal	68	Northrup-King
Melilotus alba	PI-372725	73	Alaska
Onobrychis viciaefolia	Remont	71	MSU
Oxytropis riparia	M-425	60	Three Forks, Montana
" "	M-935	69	Twin Bridges, Montana
Penstemon jamesii	NM-724	69	Los Lunas PMC
Penstemon palmeri	NM-618	69	Los Lunas PMC
Petalostemon candidum	NDL-56	65	Bridger PMC
Petalostemon purpureum	NDL-54	65	Los Lunas PMC
Sanguisorba minor	A-14173	68	Los Lunas PMC
Stachys olympica		72	MSU
Trifolium hybridum	PI-372758	73	Bridger PMC
Trifolium lupinaster	NDL-66a	65	USSR via North Dakota
Trifolium pratense	Alaskaland	57	Pullman PMC
" "	Altaswede	69	Alberta, Canada
" "	Mandan Siberian	58	Mandan, North Dakota
" "	Montgomery	56	Pullman PMC
" "	NDL-66b	58	
Vicia americana	NDL-62		Bottineau, North Dakota
Vicia cracca	NDL-115	50	Canada
Vicia tennuifolia	NDL-82	50	Mandan, North Dakota
Artemisia cana	WY-544	73	Casper, Wyoming
Artemisia nova	WY-540	73	Red Creek, Wyoming

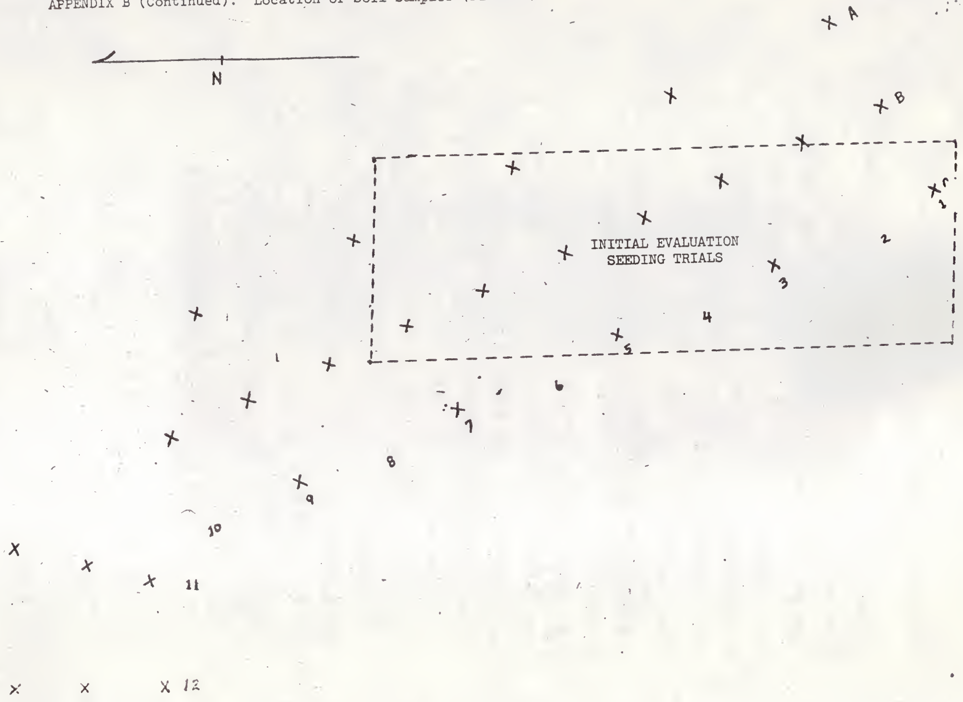
APPENDIX A. (Continued)

Scientific Name	Accession	Year	Origin
Artemisia tridentata tri.	WY-545	73	Big Piney, Wyoming
Artemisia tridentata vas.	WY-546	73	Big Piney, Wyoming
Artemisia tridentata wy.	WY-547	73	Big Piney, Wyoming
Atriplex canescens	P-15585	73	Bridger PMC
Atriplex confertifolia	M-228	60	Terry, Montana
" "	WY-543	73	Byron, Wyoming
Atriplex gardneri	P-15586	67	Bridger PMC
" "	WY-548	74	Opal, Wyoming
Cercocarpus ledifolius	WY-463	64	Kane, Wyoming
Chrysothamnus nauseosus	WY-541	73	Byron, Wyoming
Eurotia lanata	M-625	62	Decker, Montana
" "	M-966	74	Bridger, Montana
Halimodendron halodendron	WY-549	75	Cheyenne, Wyoming
Rhus trilobata	M-792	64	Granite County, Montana
Sheperdia argentea	M-834	65	Bridger PMC
Yucca glauca		73	Colstrip, Montana

APPENDIX B. Soil Analysis of Treatment and Control Soils.

Sample	pH	O.M.	P	R	Ca	Mg	Na	Texture	E.C.	S.A.R.
TREATMENT SITE										
A-1									15.7	
A-3									20.8	
A-5									12.4	
A-7									15.1	
A-9									10.6	
A-11									10.9	
A-12									13.0	
B-1									11.5	
B-2	8.4	1.20 vl	246 h	297 h	28.00	8.03	37.55	clay	22.0	8.86
B-3									19.9	
B-4									17.5	
B-5									17.5	
B-6	8.5	.95 vl	64 m	299 h	30.04	5.42	18.75	clay	22.0	4.45
B-7									18.2	
B-8									18.7	
B-9									10.0	
B-10	8.5	1.20 vl	52 m	259 h	30.04	9.35	22.75	clay	12.4	5.26
B-11									8.5	
B-12	8.5	1.25 vl	49 l	259 h	37.47	8.19	18.75	clay	15.4	3.93
C-1									18.7	
C-3									20.5	
C-5									17.2	
C-7									22.9	
C-9									16.0	
C-11									17.2	
C-12									13.6	
CONTROL SITE										
D-1									2.0	
D-2	8.0	1.62 vl	246 h	427 h	15.54	3.96	.78	clay	0.6	.27
D-3									0.4	
D-4	8.1	1.43 vl	246 h	397 h	17.53	4.12	.65	clay	0.5	.20

APPENDIX B (Continued). Location of Soil Samples (Field H).

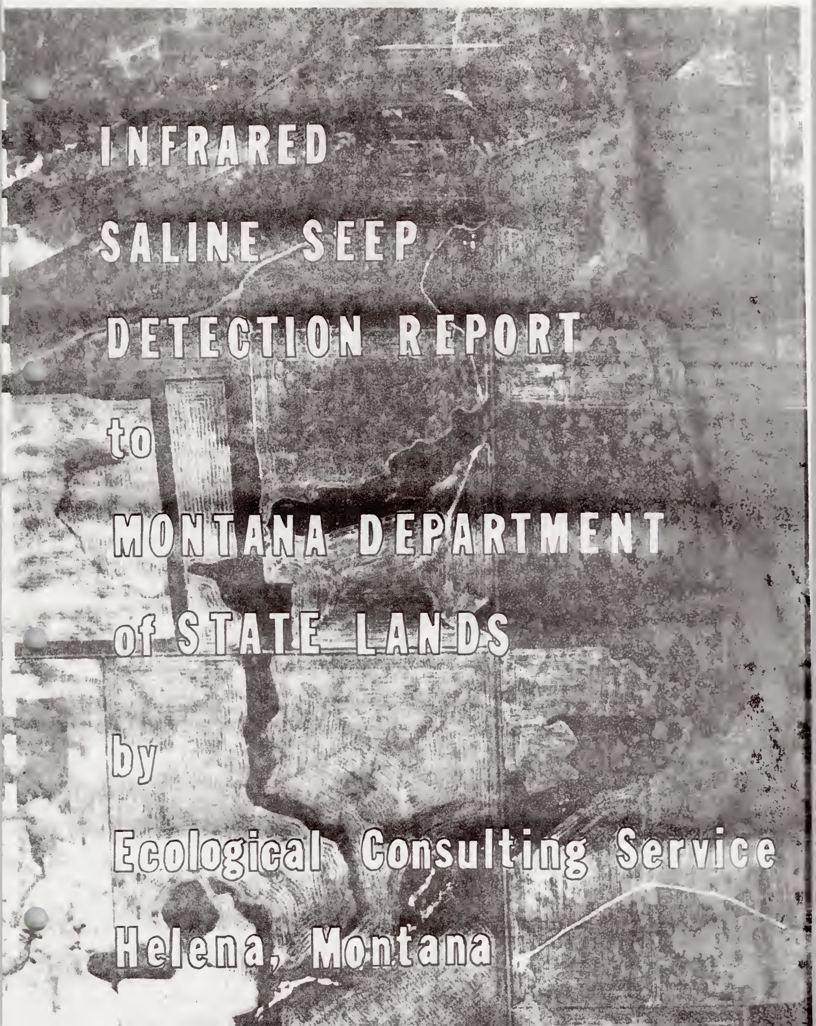


APPENDIX C. *Elymus* Accessions from Dr. Dewey, USU, Logan, Utah.

Scientific Name	Accession	Year	Origin
Elymus angustus	PI-314625	69 & 71	USSR
Elymus angustus	PI-271893	71	USSR via Canada
Elymus cinereus		70	Logan, Utah
Elymus dasystachys	PI-210988	72	Afghanistan
Elymus flavescens	Ab-484	70	Idaho
Elymus giganteus	PI-313965	70	USSR
Elymus innovatus	D-1249	73	Kananasbis, Canada
Elymus junceus		73	Logan, Utah
Elymus junceus	PI-314521	71	USSR
Elymus junceus		71	Logan, Utah
Elymus junceus	PI-314082	69 & 70	USSR
Elymus karataviensis	PI-314667	73	USSR
Elymus multicaulis	PI-314666	70	USSR
Elymus salina		71	Carbon County, Utah
Elymus salina		74	Green River, Wyoming
Elymus simplex		73 & 74	Green River, Wyoming
Elymus triticoides		72	Oregon
Elymus triticoides		71	Paradise Valley, Nev.

APPENDIX D. Plant Species Included in Seed Collection Request.

Scientific Name	Common Name
Agropyron albicans	Montana wheatgrass
Agropyron riparium	streambank wheatgrass
Beckmania syzigachne	American sloughgrass
Calamagrostis canadensis	bluejoint
Distichlis stricta	inland saltgrass
Elymus triticoides	beardless wildrye
Glyceria grandis	mannagrass
Hierochloe odorata	sweetgrass
Muhlenbergia asperafolia	alkali muhly
Phalaris arundinacea	reed canarygrass
Phragmites communis	common reed
Poa arida	plains bluegrass
Poa compressa	Canada bluegrass
Poa juncifolia	alkali bluegrass
Puccinellia airoides	Nuttall alkaligrass
Puccinellia distans	weeping alkaligrass
Spartina gracilis	alkali cordgrass
Spartina pectinata	prairie cordgrass
Scirpus paludosus	alkali bulrush
Sporobolus airoides	alkali sacaton
Oxytropis riparia	Ruby Valley pointvetch



INFRARED SALINE SEEP DETECTION REPORT

to

MONTANA DEPARTMENT of STATE LANDS

by

Ecological Consulting Service
Helena, Montana

ECOLOGICAL CONSULTING SERVICE
A DIVISION OF ECON INC.
MAIN OFFICE: HELENA, MONTANA 59601 AIRPORT WAY BUILDING WEST 1300 BLOCK, CEDAR ST. PH.: (406) 442-4650
BRANCH OFFICES: MISSOULA, MONTANA 59801 235 EAST PINE PHONE: (406) 728-5289
COLSTRIP, MONTANA 59323 P.O. BOX 453

FRANK H. DUNKLE
Environmental Consultant
Res. Phone 442-2927

ROBERT E. CARROLL
Environmental Consultant
Res. Phone 227-5727

January 8, 1975

Mr. Robert Duncan
State Lands Department
Capitol
Helena, MT 59601

Dear Bob:

As noted in the accompanying report by us to you, the definitions of the saline characteristics being sought for delineation are paramount factors in the choice of camera-original film scale when utilizing false color infrared as a remote sensing medium for such determinations.

Our recommendations are that for delineation of seep problem areas under the broader definitions, use a scale of 1:80,000 photography. It would be advisable to have it flown quad-centered because then if you so desired, photo quads could be produced from the same photography and used for your area base maps.

We recommend that for delineation of real trouble spots where intensive corrective action is planned that a camera scale of 1:24,000 be used.

It is recommended that an adequate ground control program be utilized in conjunction with the remote sensing to maximize the accuracy.

Sincerely,

Bob

Robert E. Carroll
Vice President

REC/c

ENVIRONMENTAL *RESEARCH. . .IMPACT STUDIES. . .DEVELOPMENT PLANNING. . .CONSULTING. . .REPRESENTATION*

THIS IS RECYCLED PAPER

ECOLOGICAL CONSULTING SERVICE
A DIVISION OF ECON INC.
MAIN OFFICE HELENA, MONTANA 59601 AIRPORT WAY BUILDING WEST 1300 BLOCK, CEDAR ST. PH.: (406) 442-4650
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FRANK H. DUNKLE
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Res. Phone 442-2927

ROBERT E. CARROLL
Environmental Consultant
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December 31, 1974

Mr. Ted Schwinden
Commissioner of State Lands
Attention: Mr. Robert S. Duncan
Helena, Montana 59601

Dear Bob:

Attached is the Saline Detection Report. Color infrared has proven to be a useful remote sensing medium for the detection and delineation of saline seep manifestations. As you will note in the report, the definition of saline characteristics sought has a great deal to do with the selection of the most appropriate scale of aerial infrared photography for the type of information being sought.

The principal investigator was Joe C. Elliott, assisted at various times by other members of our staff.

Sincerely,

Frank

FRANK H. DUNKLE
President

FHD:nt

RESEARCH. . .IMPACT STUDIES. . .DEVELOPMENT PLANNING. . .CONSULTING. . .REPRESENTATION

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I. INTRODUCTION

A pilot research project to evaluate the application of color infrared (CIR) photography for the detection of saline seeps in the Highwood Bench area was initiated by Ecological Consulting Service in the summer of 1974 under contract to the Montana Department of State Lands. Two scales of CIR photography (1:24,000 and 1:80,000) were flown by Mark Hurd Aerial Surveys of Minneapolis, Minnesota on September 2, 1974 and delivered to Ecological Consulting Service.

Color infrared photography for resource evaluation and management has been extensively utilized in Montana. Cosgriffe, Linne, and Meyer (1973) delineated vegetative types, agricultural lands, erosion conditions, water resources, mineral extraction and exploration sites, human habitations and other identifiable resources in the Decker-Birney area of southeastern Montana. Ecological Consulting Service (1974) completed a land use and resource evaluation similar to that of Cosgriffe et al. (1973) for the Rosebud and Coalwood planning units in southeastern Montana. Cunningham and Werth (1973) used both large and small scale infrared photography as a resource tool in the Bigfork area. Logan (no date) applied this technique to the quantitative evaluation of suspended sediment loads and sources on the Gallatin River. Carlson (1973) delineated the extent of pollution damage to vegetation in the Missoula area with large scale (1:6,000) infrared photography.

Although a limited amount of research has been done on the detection of saline seeps with infrared photography, it appears to be a feasible method of rapidly assessing the extent of this problem over large land areas. Rust and Gerbig (1974) interpreted saline soils in the Red River Valley in Minnesota with 1:40,000 and 1:10,000 scale color infrared photography taken in late October. The saline condition in the Red River Valley was related to irrigation practices which involves different processes of formation than does the saline seep condition. The severity of the irrigation saline condition was related to the amount of cereal crop growth, with growth being less on the more saline areas. They concluded that interpretation of saline soil in fallow areas could not be made with confidence since vegetative cover was not present. They also determined that 1:40,000 scale photography was adequate for broad-scale mapping efforts, but that 1:10,000 scale photography was more useful in locating relatively small saline areas.

Torgerson and Hanson (no date) performed a preliminary study concerned with the relationship between the density of aerial black and white infrared film and soil salinity. They found that a linear relationship existed between soil salinity and transmission density. The authors hope that additional data will substantiate and further define the relationships observed during the preliminary study.

II. METHODS AND MATERIALS

Color infrared photography is generally most useful for interpreting vegetative features at the peak of vegetative growth during June and the first part of July. Originally, it was planned that the Highwood Bench would be aerially photographed during June or July, but weather conditions and technical difficulties precluded this plan. The area was photographed on September 2, 1974. After studying the aerial photographs, it was apparent that September 2 was probably an excellent time to photograph the area to obtain maximum contrast between saline seeps and surrounding vegetation and soil. Because the cereal grain crops had been harvested or were in a desiccated condition, they did not show red reflectance typical of saline seeps (Figure 1). It is possible that photographs taken later in September or October would also be quite desirable since winter wheat is beginning to sprout at that time. Saline areas in cultivated fields might show up in contrast to unaffected fields due to the differential germination and growth of wheat between saline and non-saline areas.

According to Gausman (1974), leaf reflectance of near-infrared is primarily dependent on the nature of the cell wall/air space interface of the mesophyll cells and, to a lesser extent, on the cytological features of the various tissues. Healthy, actively growing plants with turgid mesophyll cells show maximum reflectance in the near infrared spectral region, whereas unhealthy or stressed plants show little or no infrared reflectance. Because saline seeps often have dense stands of salt-tolerant species such as *Kochia scoparia* and *Hordeum jubatum*, they appear as red or magenta areas on the infrared film; the surrounding land appears as gray, green, or white (Figure 2).

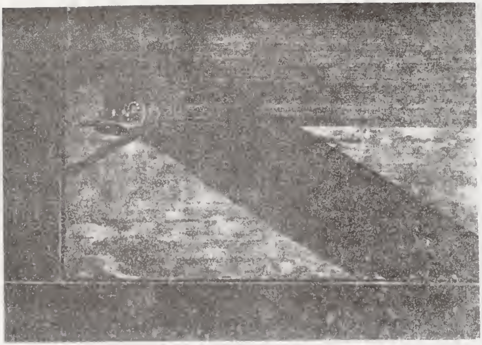


Figure 1. Non-saline cereal crop fields.

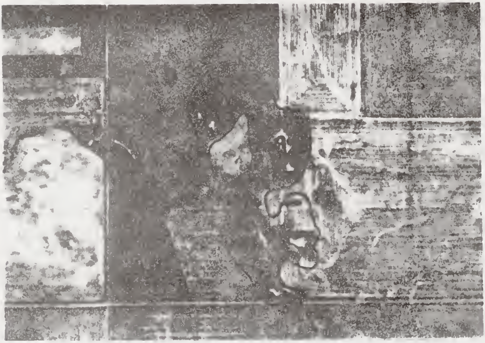


Figure 2. a. Saline seep with white salt crust in the center of the seep.
b. Non-saline affected field.

In addition to being able to discern areas of high infrared reflectance (active vegetative growth), it is also necessary to be somewhat familiar with the mechanism responsible for the formation of saline seeps. All areas with high infrared reflectance are not necessarily saline seeps. For example, seeps would not be expected to show up on the highest terrain, but one might find that strongly reflecting evergreens or non-saline higher altitude drainage patterns supporting brushy vegetation could be in vigorous condition and still reflecting strongly in the infrared region. Streambank vegetation will normally show high reflectance and strong contrast to the surrounding land in the fall. To accurately interpret saline areas, it is essential that the interpreter be aware of locations where seeps typically could occur. For example, saline seeps have been referred to as "north-slope alkali" (Warden, 1954) since they often appear on north slopes on the Highwood Bench. Also, since saline seeps require "recharge areas" (Bahls and Miller, 1974), one would not expect extensive saline seeps on the highest terrain of the area.

The first requirement for interpreting saline seeps is that the interpreter become acquainted with the general ecology and geology of the area to be interpreted. This was accomplished by discussions with Dr. Paul Brown of the Agricultural Research Service of Fort Benton on field trips to the Highwood Bench (Figure 3). Dr. Brown explained the characteristics of saline seeps and pointed out examples of seeps of varying severity. Incipient seeps, from on-the-ground observation, appeared as dark areas in cultivated fields, whereas seeps with moderate salinity supported luxuriant stands of *Kochia* and other salt-tolerant species (Figure 4). The highly saline areas did not support any

Figure 3. Field checking recently developed saline seep in a cultivated field.

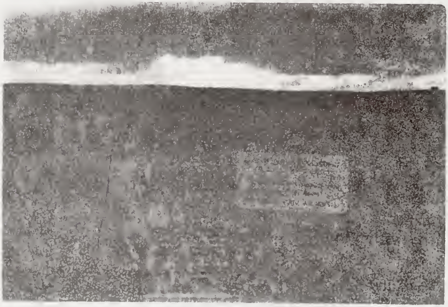


Figure 4. Saline seep with salt-tolerant species. This seep has been altered by experimental remedial measures.

vegetation, and a white crust of salts was present on the soil surface (Figure 5). At the request of the Department of State Lands, saline seeps were delineated and identified as to whether or not distinct vegetative growth and a salty crust were present. Another possible saline seep situation where salinity was elevated but no salt crust or distinct vegetation existed was not delineated since adequate ground truth would require extensive measurements of actual soil salinity at representative points. This was not possible due to the economic constraints of this study.

The mechanics of interpreting the photos and transferring the information to base maps were carried out using standard photogrammetric techniques. Kodak color infrared film was used to produce 9"x9" positive transparent color photographs. These photographs were viewed on a light table through an Old-Delft scanning steroscope with 1.5x-4.5x magnifying eye pieces. The actual delineations of seeps were made on a transparent acetate overlay of the 9"x9" transparency. The 1:80,000 scale infrared photographs were also used to produce rectified 1:24,000 photo quads as well as black and white contact prints. Black and white contact prints of the infrared photographs are inexpensive and convenient to carry in the field for ground checking.

The first scale of photography interpreted was 1:80,000. This smaller scale was interpreted before interpretation of the 1:24,000 since it was thought that a greater bias would be introduced if the larger scale (1:24,000) was interpreted first. After interpretation of the 1:80,000 photography, approximately 3 weeks were allowed to elapse before the 1:24,000 photography was interpreted. This was done to reduce the influence of one interpretation on the other; however,

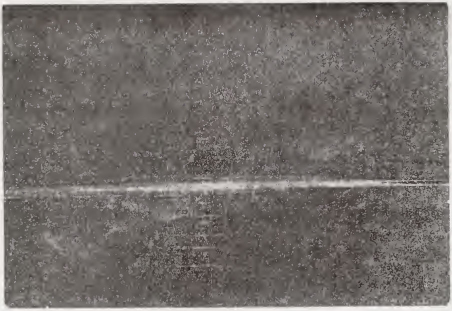


Figure 5. Saline area with extensive salt crust. This type of area is residual alkali rather than saline seep.

due to the subjective nature of photographic interpretation, one interpretation probably did influence the other. The extent to which this occurred is difficult to evaluate.

After interpreting both scales of film (1:24,000 and 1:80,000), the information was transferred to rectified photo quad base maps. Saline seeps on the 1:80,000 scale were lettered a, b, or c, depending on their characteristics. Comparable seeps for the 1:24,000 scale were lettered A, B, and C. Seeps labeled a or A were those saline areas with a white crust on the soil surface and very little vegetation (Figure 6). Seeps labeled b or B were those saline areas which had little or no salty crust apparent but with distinctive vegetative growth (Figure 7). Seeps labeled c or C were those areas with both a salty crust and distinct vegetative growth (Figure 2).

To compare the two scales of film, mylar overlays were placed over the orthophoto quads, and saline seeps were delineated separately for each scale of photography. This information was transferred from 9"x9" acetate overlays of the infrared photographs with the aid of a mapping device known as a Map-o-Graph 55C. A map-o-graph is a reflecting projector with a variable control for changing the map scale. Delineations on acetate overlays are projected from this device onto a base map of a given scale. The total area covered by saline seeps was calculated by using a dot grid with the dots placed 2.5 mm. apart (Bryan, 1942).

Field checking of interpretations was performed with the assistance of Dr. Paul Brown of Fort Benton and Les Pederson of the Department of State Lands. Some areas delineated were familiar to Dr. Brown, so it was not necessary to visit every location. Questionable areas unfamiliar to Dr. Brown were visited to determine the accuracy of interpretation.

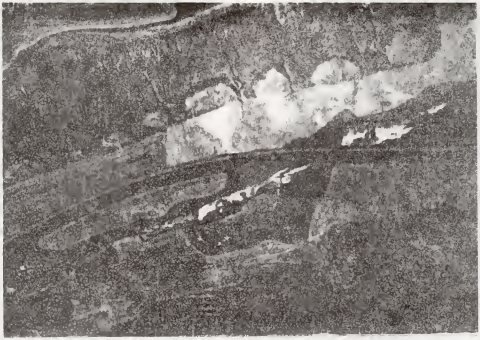


Figure 6. a. Saline areas with salt crust on soil.

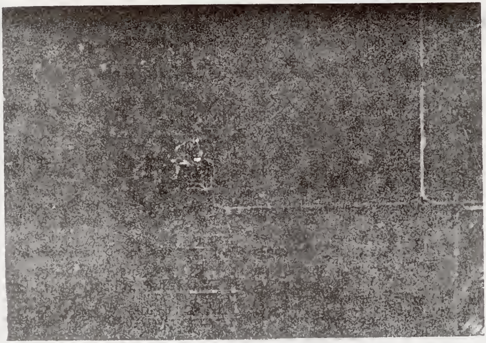


Figure 7. a. Saline areas with salt-tolerant plant species.
b. Non-saline "pot hole" area.

The interpretation of saline seeps for this study was conservative because only those areas showing distinct features were delineated. Distinct features were salt crust and/or vegetative patterns of *Kochia* and other salt-tolerant species. Some salt-affected areas, although visible (such as "seeped drainageways"), were not, generally, delineated.

III. RESULTS AND DISCUSSION

Interpretation of saline seep areas was based on color and texture contrasts between saline seeps and surrounding fallow or fields of cereal crops (Figure 8). Saline seeps appeared as magenta areas, while fallow fields appeared silver, and cropped fields appeared greenish. Fields with less severe saline damage often had a darker or mottled appearance.

Less severely damaged saline areas can also appear somewhat greenish and darker or more mottled in contrast to non damaged areas. This darker green and mottling is partially due to the mechanism of seeps. In general, the seep may be providing enough moisture to allow denser vegetation growth but not enough salt level to damage the growth. Thus, the seep area could look greenish, similar to other vegetation in fall dormancy. The moisture availability which allowed denser vegetation to remain vigorous in comparison to other vegetation later into the fall would account for the darker tone of green. The "mottling" texture is probably due to soils differences. Because the past year had lower precipitation than normal, less severely affected saline areas were not as apparent as they may have been during years of high precipitation (Brown, 1974).

By comparing the acreage figures for saline seeps on a selected area of the Highwood Bench north of the Big Sag area (see orthophoto quads and acetate overlays) for both scales of photography, the data in Table I were generated. The area selected for comparison of the two scales on the Highwood Bench was chosen since it was the area that was photographed at both scales. Photographic coverage of much of the

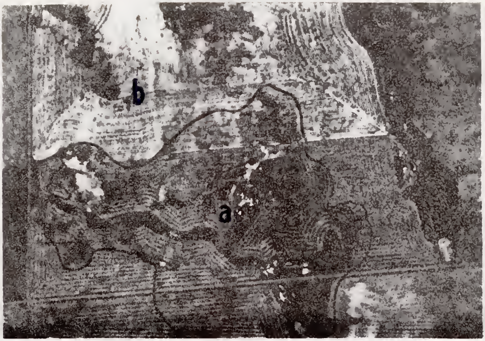


Figure 8. a. Extensive saline seep area.
b. Cropped field.

Highwood Bench was available at the 1:80,000 scale (Figure 9), whereas a strip down the middle of the bench overlapping a portion of each 1:80,000 frame was photographed at the 1:24,000 scale. Therefore, the acreage figures on Table I should not be confused with acreage figures for the entire Highwood Bench calculated by other researchers using various methods.

TABLE I. ACREAGE OF SALINE SEEPS DELINEATED FROM 1:80,000 SCALE PHOTOGRAPHY AND 1:24,000 PHOTOGRAPHY

Acreage Determined from 1:24,000 Scale Photography

Type Seep	Acreage
A	205
B	873
C	1,321
Total	2,399

Acreage Determined from 1:80,000 Scale Photography

Type Seep	Acreage
A	208
B	328
	1,324
Total	1,860

In comparing the acreage figures for both scales, saline seep classifications A, a, and C, c are very close to the same values, while acreage figures for the type B, b seeps vary considerably. It is purely coincidental that the acreage figures for types A, a and C, c are nearly the same. When a size distribution of seeps delineated at both scales is compared (Tables II, III, IV), several trends are apparent. At

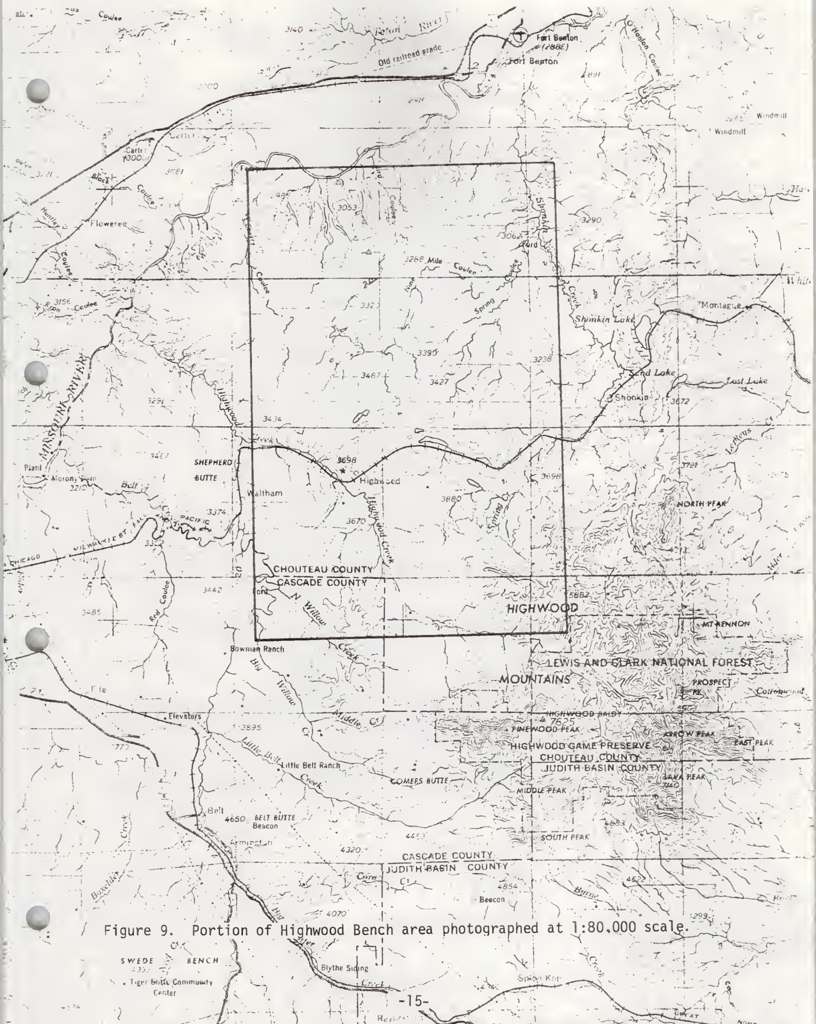
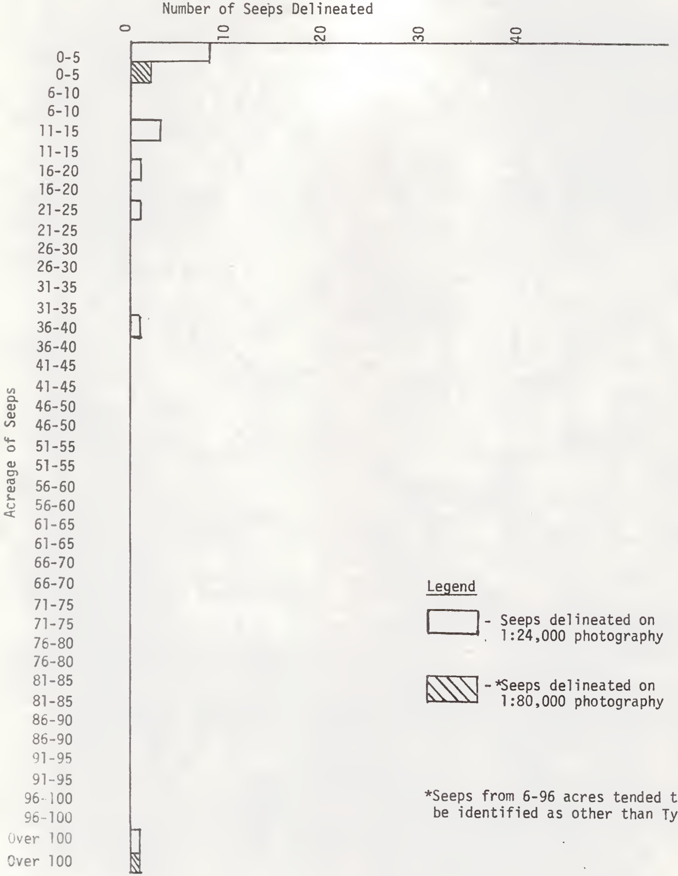


Figure 9. Portion of Highwood Bench area photographed at 1:80,000 scale.

TABLE II. SIZE CLASS DISTRIBUTION FOR TYPE A SALINE SEEPS INTERPRETED FROM TWO SCALES OF PHOTOGRAPHY



*Seeps from 6-96 acres tended to be identified as other than Type A.

TABLE III. SIZE CLASS DISTRIBUTION FOR TYPE B SALINE SEEPS INTERPRETED FROM TWO SCALES OF PHOTOGRAPHY

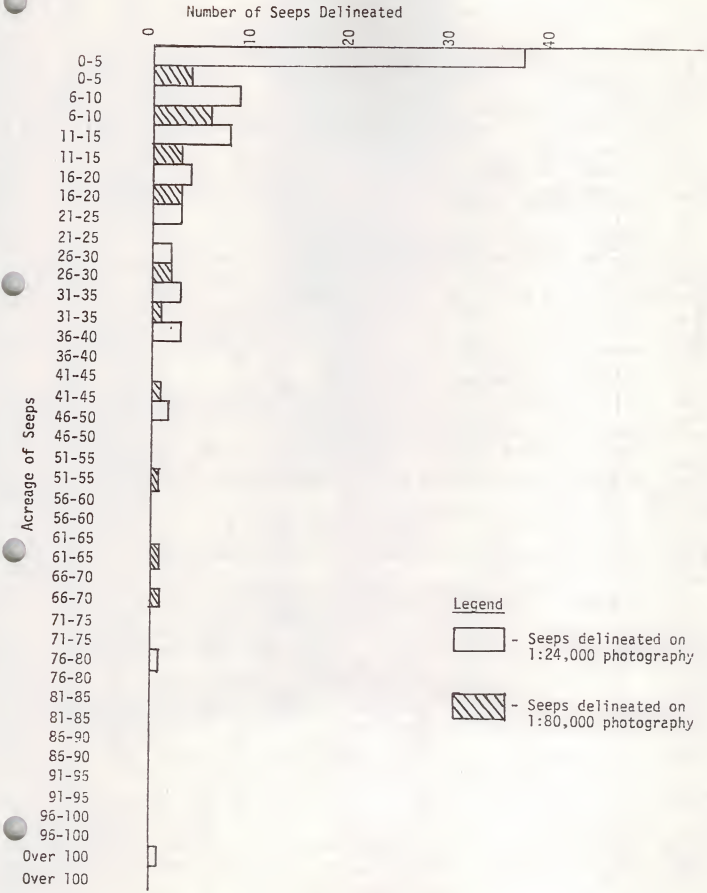
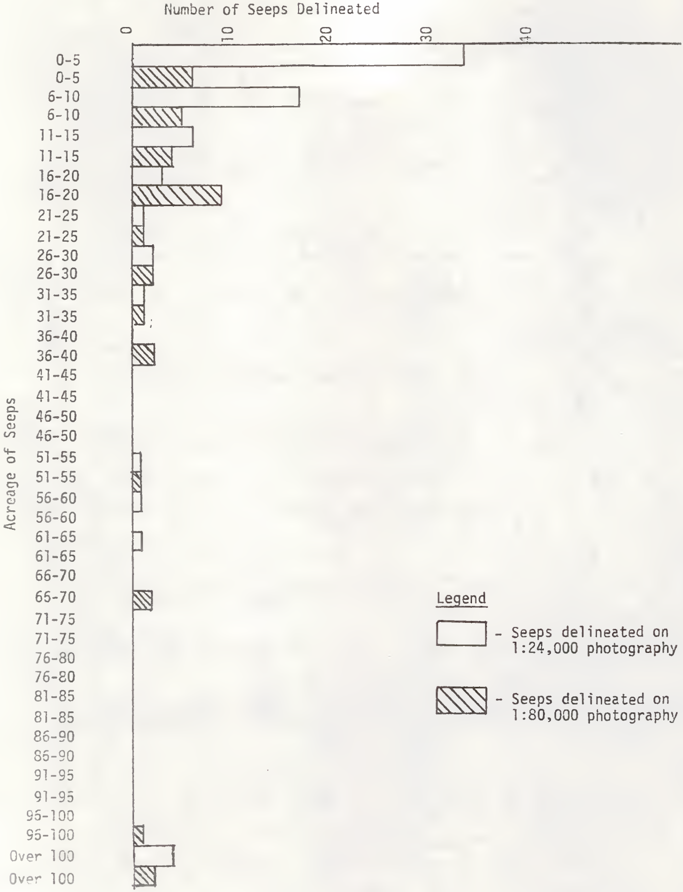


TABLE IV. SIZE CLASS DISTRIBUTION FOR TYPE C SALINE SEEPS INTERPRETED FROM TWO SCALES OF PHOTOGRAPHY



the 1:24,000 scale, seeps in the 0-5 acre size class were delineated much more frequently than seeps of the same size class at the 1:80,000 scale. For the type B seeps (1:24,000), 38 seeps were delineated in 0-5 acre size class on 1:24,000 scale photography, and four type b (1:80,000) seeps were recorded in this size class at the 1:80,000 scale. The acreage figures for the type B seeps were also approximately two-fold higher for the 1:24,000 scale interpretation. The same pattern was also evident for seep types A, a and C, c. More seeps of the 0-5 acre size range for these types were recorded from the 1:24,000 scale film than from the 1:80,000 scale. It is, therefore, thought to be coincidental that acreage figures for the A, a and C, c type seeps were nearly the same for the 1:24,000 and 1:80,000 delineations. Although there were more individual seeps delineated at the 1:24,000 scale, they were smaller in size. Although the number of seeps was smaller for the 1:80,000 delineation, the average acreage of the seeps delineated was larger.

At the 1:24,000 scale, severely affected saline areas were often characterized by the delineation of many small seeps, whereas at 1:80,000 the same area was often delineated as one or several larger seeps. For practical considerations, the broader delineations interpreted from the 1:80,000 scale are probably adequate since seep boundaries are fairly dynamic depending on such factors as yearly precipitation, current agricultural practices,and the season during which the photographs are taken. In areas where incipient saline damage is occurring,or in less severely affected areas, very small seeps were often not interpreted on the 1:80,000 photography. Of 153 seeps delineated on the 1:24,000 scale, 94 of these were also interpreted on the 1:80,000 scale and 59 of these were not. From this consideration it is calculated that the accuracy of seep detection for 1:80,000 photography is 57% (± 12%) compared to 92% (± 8.1%) for 1:24,000 photography (Tables V, VI, VII).

TABLE V. ACCURACY OF 1:24,000 INTERPRETATION

Number of Saline Seeps Field-checked:	104
Number of Saline Seeps Correctly Interpreted:	101
Number of Saline Seeps Interpreted Incorrectly:	3
Number of Saline Seeps Missed:	5
Percent Accuracy of Interpretation:	92%

TABLE VI. ACCURACY OF 1:80,000 INTERPRETATION

Number of Saline Seeps Considered:	153
Number of Saline Seeps Delineated on Both Scales of Photography:	94
Number of Saline Seeps Delineated on 1:24,000 Scale but Not on 1:80,000:	59
Percent Accuracy of 1:24,000 Interpretation (Table V):	92%
Percent Accuracy of 1:80,000 Interpretation (86 ÷ 153 x 100):	57%

TABLE VII. ACCURACY CALCULATIONS

Formula Used (From Arkin, H. and R. R. Colton, 1967):

$$\text{Standard Deviation } (\sigma\%) = \left(\frac{\%\text{ accuracy x }\%\text{ inaccuracy}}{\text{number of seeps considered}}\right)^{\frac{1}{2}}$$

Accuracy Calculation at 1:80,000 Scale:

$$\sigma\% = \left(\frac{57 \times 43}{153}\right)^{\frac{1}{2}} = 4.0\% \text{ (Standard Deviation)}$$

Accuracy Calculation at 1:24,000 Scale:

$$\sigma\% = \left(\frac{92 \times 8}{104}\right)^{\frac{1}{2}} = 2.7\% \text{ (Standard Deviation)}$$

Table VII (continued):

At 1:80,000 Scale: Certainty of 99.7% that accuracy is 57% ± 12%.

At 1:24,000 Scale: Certainty of 99.7% that accuracy is 92% ± 8.1%.

$$\sigma D = [(40)^2 \times (2.7)^2]^{\frac{1}{2}} = 4.8\%$$

Actual difference is $92-57 = 7.5\sigma_D$

Implication: 99.9999% certainty that the difference in accuracy is due to something other than statistical variation--probably due to a scale difference.

Several problems with seep detection at both scales arise from farming methods and natural variations in soil reflectance other than those caused by salinity. Areas of soil with a heavy salt crust appear bright white, whereas most normal soil appears as less intense white. It is usually possible to discern areas with salt crusts from most unaffected soils. Some soils reflect intense white while at the same time having low salinity levels. These low saline soils are found in areas where water accumulates during wet periods and drains fairly rapidly leaching out the salts. These "pot hole" areas are important recharge areas for seeps in the surrounding areas, even though they are not highly saline. Many of these areas on the bench have been drained by the construction of drainage ditches and can be recognized because these ditches are apparent on the photographs (Figure 10). Also, "pot holes" often are fairly round, oval, or regular in outline, whereas seeps are usually irregular in outline.

The detection of saline-affected areas on recently cultivated fallow fields was difficult since during relatively dry years these fields were

Figure 10. a. "Pot hole" area with drainage canal.

often cultivated. They can be recognized, however, due to their irregular dark, mottled appearance (Figure 11) and their proximity to intensely seeped drainageways. Although these less severely affected areas were not included in the initial interpretative attempt, they are visible on the infrared photographs and can be delineated if a broad definition of saline seeps is desired. To accomplish this, however, extensive ground data would have to be gathered to confirm that areas recorded as dark or mottled on the film actually have correspondingly high salinity levels. These areas of incipient seep are definitely of practical importance since they could affect agricultural production and become too wet to farm during relatively wet years. Therefore, depending on how broadly the concept of saline seeped land is interpreted and depending upon additional quantitative data, incipient and less severely affected saline areas could also be delineated and included in total acreage figures for the Highwood Bench. A broad concept of saline seep would increase the usefulness of small scale 1:80,000 film.

Field measurements of salinity levels in representative seeps would increase the value of infrared photography for saline seep detection. Measurements of soil salinity across representative seeps and the subsequent construction of isocontours between areas of similar salinity would be useful. Precise determinations of the relationship between color infrared reflectance and soil salinity could then be made. The limits of detection for a given level of salinity for different scales of photography could be determined with these additional data.

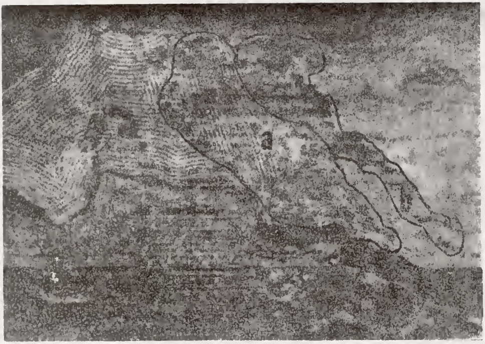


Figure 11.
a. Less severely affected saline area.
b. More severely affected saline area.
c. Intensely seeped drainageway.

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IONTANA STATE UNIVERSITY
Agricultural Experiment Station
Cooperative Extension Service

Saline Seep Program

Room 214—Linfield Hall, Bozeman, Montana 59715
Phone (406) 994-4681

July 25, 1975

Mr. Les Pederson
Department of State Lands
Helena, Montana 59601

Dear Les:

I am replying to your request for an annual report for the fiscal year 1974-75 as per agreement signed by the State Department of Lands, the Montana Agricultural Experiment Station and the Cooperative Extension Service. As it is in the middle of our growing season, little can be added to the two reports already sent to your office, namely the report to the State Department of Lands dated December 20, 1974 and the listing of the plantings made in the spring of 1975 throughout Montana. The later report was assembled this spring for updating the State Advisory Council.

To date we cannot give you a final report on funding for 1974-75 as we have not received the June IBM printouts. However, we are enclosing a financial statement based on our office records. We will send a finalized report as soon as all accounts are paid and reconciled.

Since January other major activities included the hiring of a Research Associate in our office in Bozeman and the hiring of two technicians, one at Conrad and one at Sidney. The technicians were hired under the Training Program offered by the State Employment Office. Problems encountered revolved around the weather and difficulties establishing demonstration and research plots referred to above. Weather also cancelled the Tri-State Remote Sensing flights scheduled for the Highwood Bench and Hailstone Basin for three consecutive weeks in June. Little was accomplished in this area to date. The pilot program in Stillwater County for mapping saline seeps by neighborhoods on a one-to-one basis was 80% completed by the County Agent and Soil Conservation Service District Conservationist.

Trusting this letter will update any required reports. You can be assured that the report next January will give in detail the results of all demonstrations and research trials conducted under the program for the detection and abatement of saline seeps.

Very truly yours,

JKrall

Jim Krall
Program Leader

JK:gc
Enclosure
cc: J. A. Asleson
Carl Hoffman
Kurt Feltner
Charles Rust

EXPENDITURES

Through June 30, 1975

BUDGETED	Agricultural Exp. Station	Cooperative Ext. Service	Total
	$37,500.00	$37,500.00	$75,000.00
EXPENDITURES			
Personal Services	19,664.53	19,664.55	39,329.08
Capital Equipment	10,447.46	5,796.58	16,244.04
Herbicides, Seeds, Fertilizer	805.40	803.61	1,609.01
Travel	893.56	3,724.36	4,617.92
Wages (Hourly)	286.00	2,643.75	2,929.75
Operating Expense	4,366.46	4,766.75	9,133.25
Total	$36,463.41	$37,399.60	$73,863.05
Balance			$ 1,136.95*

*This amount may be subject to reduction due to last minute bills as yet unpaid or changes in benefit amounts for classified employees not yet shown on printout.

SALINE SEEP PROGRAM

MONTANA STATE UNIVERSITY
Bozeman, Montana

KRALL - JOHNSON
Spring - 1975

BELOW IS A LISTING OF SPRING PLANTINGS MADE IN 1975 FOR CROPPING SYSTEMS EVALUATION

I. Herbicide-No-till Plantings

  A. To determine effectiveness of foliar spray treatments compared to tillage.

  B. If coulter drill is any better than drill used by farmers.

  C. If opening up the land is superior to slot planting or leaving the stubble standing.

  D. To evaluate no-till coulter equipped drill in different kinds and amounts of crop residue.

  E. Present locations (9) Schneidts at Molt, Barber at Denton, Anderson at Geraldine, Erickson at Power, Quinn at Big Sandy, Bokma at Conrad, Rankin at Sunburst, Arneklev at Antelope, Baue at Sioux Pass.

II. Evaluate various crops with no-till systems based on seed size (from alfalfa up to corn), including alfalfa, sorghum x sudan grass, safflower, barley, spring wheat, peas, corn, and sunflowers.

  A. Present locations (6) Erickson at Power, Bokma at Conrad, Anderson at Geraldine, Baue at Sioux Bass, Research Center at Sidney, Hoegland at Broadview.

III. Compare fall, spring and pre-emergence foliar herbicide treatment with winter wheat, spring wheat, barley and corn on land sown to spring wheat, winter wheat, barley and fallow last year.

  A. Present location (1) Research Center at Huntley.

IV. Evaluate no-till openers and packer wheels

  A. Three openers - shoe, lister, and double disk.

  B. Three packer wheels - ribbed, concave, and round.

  C. In addition mechanisms for depth control and disk covers will be tested.

  D. Present locations (2) Research Center at Moccasin, Agronomy farm at Bozeman.

V. Peas and other legumes for N fixation and seed yield.

  A. Primarily Austrian winter peas. Soil samples taken at seeding and will be taken again this fall.

  B. Present locations (5) Barber at Denton (lentils & peas), Erickson at Power, Bokma at Conrad, Hoegland at Broadview, Lewis at Sioux Pass.

Spring planting: (continued)

VI. Alfalfa Establishment

- A. Trials using preplant herbicides, companion crops and different row widths and seeding directions.
- B. Present locations (2) Holzer Brothers at Stanford, Erickson at Power.

VII. Late planted corn for grazing.

- A. To be planted after the second fallow operation and the means of using up some of the abundant moisture.
- B. Locations (4) Holzer Brothers at Stanford, Erickson at Power, Lindberg at Conrad, Dennison at Sidney.

VIII. Screening trials for salt tolerant crops, including both annuals and perennials. Some of the more promising crops that should show salt tolerance includes the World Collection of barley, safflower and spring wheat.

- A. Locations (6) Schneidt at Molt, Research Center at Huntley, Holzer Brothers at Stanford, Sommerfeld at Power, Bokma at Conrad, Baue at Sioux Pass.

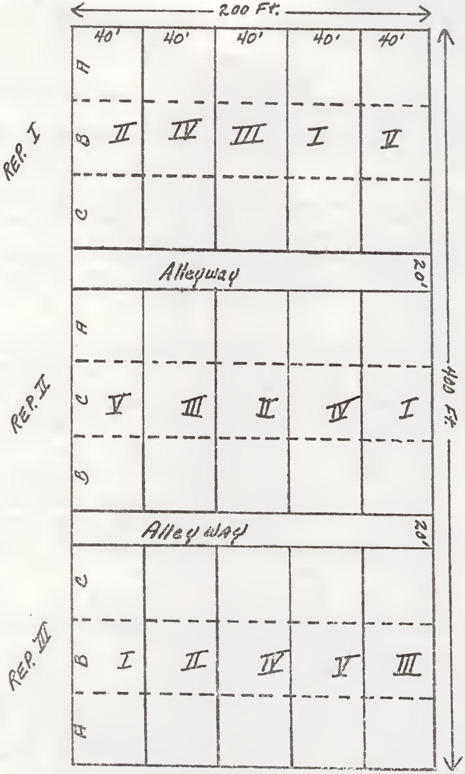
IX. Miscellaneous Tests

- A. Severald miscellaneous tests are being conducted including:
    1. Fertilizing kochia to determine its yield and nitrate content.
        - a. Location - Bokma at Conrad.
    2. Making fourwing saltbush plantings for forage production and quality.
        - a. Locations - Research Center at Huntley, Baue at Sioux Pass.
    3. A faba/bean variety trial to determine the yield and lisine content.
        - a. Locations - Research Centers at Moccasin, Sidney, Huntley, Baue at Sidney.
    4. Frost seeding of spring wheat and barley in comparison to regular planting.
        - a. Location - Research Center at Huntley.
    5. Planting of winter graze on seep site.
        - a. Location - Holzer Brothers at Stanford.
    6. Cicer Milkvetch and tall fescue planting on seep site.
        - a. Location - Lewis at Sioux Pass
- B. Total locations - 10.

Planting to be accomplished this summer including perennial and annual crops on saline seeps that were too wet to plant this pring and make observation on the effect of chemical spray application on the control of after harvest weeds (kochia and Russian thistle). Several alfalfa fields were tested for N fixation. Total Demonstrations and plantings - 43.

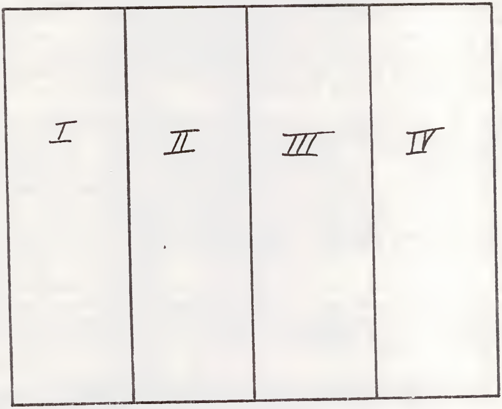
ESTABLISHMENT OF DRYLAND ALFALFA USING DIFFERENT HERBICIDES.

I	Eptam - preplant	IV	Eptam & Balan mixture - preplant
II	Balan - preplant	V	No treatment
III	Roundup - preemergency		



A. Kurb-W-50-Put on in fall.
B. Sencor - Put on in fall.
C. No fall treatment.

DIVIDE REMAINING AREA OF STRIP INTO FOUR PLOTS.



I. Seed at 90° angles - legume and the small grains, 1)barley, 2)oats.
II. Seed small grain in alternate rows with alfalfa.
III. Solid stand - do not seed with a cereal grain.
IV. Seed alfalfa only - 20" or 14" rows.

REPORT TO

DEPARTMENT OF STATE LANDS

On The

SALINE SEEP PROGRAM
MONTANA STATE UNIVERSITY
Bozeman, Montana
December 20, 1974

Introduction

A cooperative agreement between Montana State University and the Department of State Lands was signed on July 15, 1974. This agreement called for the establishment of two positions, a cropping systems agronomist and a crop-weed scientist. This portion of the program was funded for half Experiment Station and half Cooperative Extension, with the program being attached to the Plant and Soil Science Department. Funds were also included for continuation of research on water flow studies being conducted by Dr. Hayden Ferguson.

On July 15, James L. Krall, Superintendent and Agronomist at the Southern Agricultural Research Center at Huntley, was transferred to the Saline Seep Program as Program Leader and Cropping Systems Agronomist. He was allowed to phase out his research program at Huntley prior to establishing an office at Montana State University, Bozeman. He made the final move on September 22, but much of the survey work reported later was conducted prior to his move to Bozeman. The second position (crop-weed scientist) at this report has not been filled. Two promising candidates have been interviewed. The position should be filled soon.

On July 30, 1974, Dean Joe Asleson appointed a Montana State University Saline Seep Steering Committee. This eleven-member committee of scientists knowledgeable about and involved in some part of the Saline Seep Program, and representing the Experiment Station (including Research Centers) and Cooperative Extension functions, are:

Kurt Feltner, Plant and Soil Science Department Head, Chairman
Martin Burris, Associate Director, Agricultural Experiment Station
Charles Rust, Program Coordinator, Cooperative Extension Service
Hayden Ferguson, Soil Scientist, Agricultural Experiment Station
Glenn Hartman, Superintendent, Eastern Agricultural Research Center
Jesse Hodgson, U.S.D.A., A.R.S., Weed Scientist
Oscar Burt, Agricultural Economist, Agricultural Experiment Station
Gene Quenemoen, Agricultural Economist, Cooperative Extension Service
Art Shaw, Crop Scientist, Cooperative Extension Service
Mike Jackson, Weed Scientist, Cooperative Extension Service
Charles Smith, Soil Scientist, Cooperative Extension Service

The three-fold charge to that Committee was:

1. Review all extension and research programs proposed and/or being conducted by the Cooperative Extension Service and the Agricultural

Experiment Station to assure maximum productivity and coordination with saline seep programs being conducted by other agencies in the state.

2. Review program staffing and recommend additional staffing including job descriptions and qualifications required, when additional funding becomes available.
3. Recommend distribution of salary and other support from grant and/or contract funds (among eligible agencies) based on recommended relative emphasis as between extension and research.

The entire committee met on August 8, 1974, and again on November 22, 1974; minutes of those meetings were forwarded to the State Department of Lands. Fragments of the committee have met on numerous occasions, usually on the Montana State University campus. The next meeting of the entire committee is planned during the Plant and Soil Planning Converence, March 3-7, 1975.

Feltner represents the above-mentioned steering committee on the State CRD Technical Committee on Saline Seep. It should be pointed out that input to the M.S.U. Saline Seep Program is not limited to this steering committee. Jim Krall has worked closely with Paul Brown, A.R.S. soil scientist now located at Fort Benton, with Marvin Miller, hydrologist at Montana Tech, with Research Center personnel, with A.R.S. scientists at Sidney, and even with concerned scientists in the Dakotas (e.g., the three-state meeting on saline seep held in Billings on September 18-19, 1974, which was attended by 18 persons).

Objectives Of The Program

1. Develop and implement dryland cropping systems and associated technology that will be useful in the prevention of the spread of saline seep.
2. Devise means of recliaming saline seep areas already in existence.
3. To further define the cause and extent of saline seeps in Montana.

Efforts Made To Accomplish Objectives

This program was initiated July 15, in the middle of the growing season, so little new experimentation on different cropping systems was initiated. Instead, most of the fall months were spent surveying the trouble areas for demonstration cites, locating farm operators already using control practices, helping establish alkali associations for the neighborhood approach to control programs. Due to different climatic conditions, types of cropping systems used in the area, geological formations, and research efforts already being made, the following areas were selected for concentrated effort:

1. The western triangle area (Conrad, Dutton, Cutbank, Sunburst, and Shelby.
2. The northern portion of the Judith Basin (Coffee Creek and Denton).

3. Hailstone, wheat, hay and commanche basin areas (Broadview, Molt, and Rapelje).

4. Northeastern Montana (Scobey, Plentywood and Froid).

5. Eastern Montana, primarily Fallon and Beavercreek drainages (Wibaux and Baker).

The Highwood Bench area was purposely left out of concentrated effort because it is felt that considerable effort on the control of saline seep is already being conducted by the U.S.D.A., Agricultural Research Service in this area. It should be understood that upon request help will be given to any other areas having saline seep problems.

Research activities under this program this fall consists of:

1. Continuation of research that involves some aspect of cropping systems to include no-till planting, frost seeding barley, selection of salt tolerant barley varieties and other crops, annual snow trapping barriers, and the testing of furrow openers for stubble planting, primarily at Huntley.

2. Selection of sites for new crop plantings, namely at Denton, Conrad, and Broadview.

3. Letters of inquiry into new crops, herbicides, and machinery for alternative cropping systems.

4. Review of literature and Experiment Station research reports on any of the aspects of cropping systems that could be applied to this program.

5. Cooperative efforts were made for the publication of a bulletin on alfalfa for the control of saline seep. This will include data obtained by Paul Brown, Agricultural Research Service, Fort Benton; from Marvin Miller, Bureau of Mines, Butte; and Hayden Ferguson, Montana Agricultural Experiment Station, Bozeman. This bulletin will be written by J. L. Krall and should be published for grower use next spring.

Since July, the cropping system agronomist has made the following contributions to the Extension phase of the program:

1. Meetings attended (10-150 people).	18
2. Talks to farm groups concerning saline seeps.	9
3. News articles on saline seeps.	4
4. Radio and TV tapes (15 min., MTN network).	1
5. Annual research reports relating to saline seep.	5
6. Experiment station publications on research.	2
7. Help organize slide presentations.	2

Since July, Dr. Hayden Ferguson's research activities on saline seep have been primarily in the Broadview area and consist of the following:

1. Determine the direction of water flow in the research area at Broadview.
2. Make plantings of alfalfa and other legumes, including sainfoin, at the Broadview ranch.
3. Make plantings of annual barriers for snow trapping at Broadview and on the Highwood Bench.
4. Complete analyses of soil samples obtained on the Highwood Bench for comparison of salts in crop land versus native sod.

Preliminary Conclusions

Through discussions with individual farmers and farm groups, it was concluded that operators would be more willing to try new cropping practices as groups rather than "going it alone". Furthermore, contracting crops, obtaining new machinery, and marketing would be easier to implement in groups, rather than by any single individual.

The pertinent results obtained from research underway previous to the initiation of the present program are as follows:

1. No-till planting increased yields of annual cropped barley by 300 lbs/acre and was estimated to be equal to over 1" of precipitation.
2. Slot planting in stubble is more effective than open furrow drills.
3. Roundup (glyphosate) herbicide was effective for control of all vegetative growth prior to no-till planting.
4. Frost seeded barley (early March) has resulted in earlier harvest and would spread farm work load during seeding when annual cropping.
5. Harvesting barley head-chop with a forage harvestor and ensiling proved to be an excellent cattle feed and would spread the combine work load when annual cropping.
6. Annual snow trapping barriers were ineffective in southern Montana where snow drifting is minimum.
7. Peas and small grains for hay would be effective in a rotation as the peas would add nearly 30 lbs/acre of nitrogen.
8. Corn grown in 36" rows was superior to other warm season crops as an annual forage.
9. The "salt garden" approach which employs the practice of sowing plants across increasing amounts of salinity proved to be a satisfactory method of testing crops for salt tolerance.

10. It was found on the Highwood Bench that cropped land had approximately one-half as much salt to a depth of 12 feet than native sod. This indicates that one-half of the salts (primarily Na and Mg) on crop lands has been leached down into the water table. On an acre basis, this is estimated to be nearly 120 tons/acre of salt.

11. Techniques for measuring and mathematically evaluating the direction and amount of water flow in seep areas have been successfully developed.

Difficulties Encountered

Due to the annual method of funding, it has been difficult to:

1. Establish long-term experiments and demonstrations.

2. Hire qualified personnel.

3. Make decisions on procurement of equipment, supplies, and land rental.

Other difficulties:

1. Farm operators in general are reluctant to change from the traditional crop-fallow system. Payment incentives for losses due to new practices would be helpful.

2. Inaccurate saline seep surveys make it difficult to find research and demonstration sites.

3. The feed grain-cattle syndrome makes it difficult to encourage operators to try practices other than cash grains.

4. The dryland farmers are locked into large machinery which is difficult to convert into more intensive agriculture.

Future Plans

To research those aspects of cropping systems that are not being studied extensively by the Montana Agricultural Experiment Station, including Research Center personnel, to include:

1. Control after-harvest weeds (kochia, Russian Thistle, pigeongrass).

2. Continue no-till planting trials and associated factors (herbicides, furrow openers, seeding rates, and fertility levels).

3. Continue to evaluate annual barriers for their effectiveness for snow trapping in different locations.

4. Continue to search for and develop salt tolerant crops and varieties with emphasis on a salt tolerant variety of barley.

5. Continue to frost seed barley to ascertain if this practice is feasible.

6. To accumulate data helpful in the determination of the economic aspect of annual cropping versus fallowing.

7. Measure the mellowness of land cropped annually versus fallowed land with strain gages (energy requirements for tillage).

8. Further evaluate peas and other legumes for their nitrogen contribution to the soil.

9. Try to establish different crop rotations with alfalfa to lower the water table, then revert back to cash grains (three years alfalfa, then six to ten years of alternate fallow).

10. Assist the State C.R.D. Technical Committee on Saline Seep with its' effort to determine accurately the nature and extent of saline seep seep in Montana.

To continue Extension's program involving:

1. News releases and radio and TV programs.

2. Write short articles on certain aspects for popular magazines and leaflets.

3. Report research underway and completed in annual reports and bulletins.

4. Help various saline seep associations by visitation and obtaining other help when needed.

5. Give talks on all the aspects of saline seeps to rural and urban groups to help them understand the problem.

Expenditures

Through December 20, 1974

	Agricultural Exp. Station	Cooperative Ext. Service	Total
BUDGETED	$37,500.00	$37,500.00	$75,000.00
EXPENDITURES			
Personal Services*	18,160.22	18,160.21	36,320.43
Capital	5,000.00	1,066.75	6,066.75
Operating Expense	1,501.56	1,212.17	2,713.73
Other	-----	------	-----
Total	$24,661.78	$20,439.13	$45,100.91
Balance (Work Funds)	$12,838.22	$17,060.87	$29,899.09

*Includes encumbered funds for salaries through June 30, 1974.

SALINE SEEP PROGRAM

1975 ANNUAL PROGRESS REPORT

To

The Montana Department of State Lands
Helena, Montana

Prepared By

James L. Krall, Program Leader and Cropping Systems Agronomist
and Wally Johnson, Research Associate
Montana State University, Bozeman, Montana

This report is a cooperative effort of
the Cooperative Extension Service
and the Agricultural Experiment Station
and published by
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INTRODUCTION

This report contains the research and extension activities conducted from January 1, 1975, through December 31, 1975. The purpose is not only to inform administration, advisory councils and the general public on the programs accomplishment, but also to provide a historical documentation for future reference. Since the Saline Seep Program is scheduled only for a short period of time, all of the research reports will be included in the Plant and Soil Science annual committee reports assembled annually. As an example, reports on weed control will appear in the weed report; soils in soils, etc.

ADMINISTRATIVE ACTIVITIES

It is the purpose of this portion of this report to present the non-research and extension activities of the saline seep program. Included will be the source and expenditures of funds, staffing, both farm and agency cooperators, and advisory councils.

Employees

The following list gives the full time employees, rank, date employed and location.

Krall, James L., Cropping Systems Agronomist and Program Leader, August-1974, 214 Linfield Hall, Montana State University, Bozeman.

Johnson, Wally, Research Associate, March-1975, 214 Linfield Hall, (Great Falls, Montana, from June through October).

Panasuk, Toby, Agricultural Research Technician III, April-1975, Eastern Agricultural Research Center, Sidney, Montana.

Matheson, Harvey, Agricultural Research Technician III, April-1975, Conrad, Montana.

Crane, Geraldine, Secretary II, October-1974, 214 Linfield Hall.

Holzer, Jane, Research Technician, January-1975, 214 Linfield Hall.

All of the above employees are funded one-half by the Agricultural Experiment Station and one-half by the Cooperative Extension Service. Retirement benefits are under the Agricultural Experiment Station. Toby Panasuk and Harvey Matheson were hired under a training program through the Comprehensive Employment and Training Act (CETA) for 15 weeks. Crane changed to half time (.50 FTE) starting July 1, 1975.

During 1975 arrangements were made to place personnel in saline seep areas that were distant from Bozeman. It was soon found that considerable time could be spent traveling. It was decided to locate a technician at Conrad and one at Sidney. Furthermore, it was felt that local persons should be hired for the position. Thus, Toby Panasuk of Sidney was located at Eastern Agricultural Research Center and Harvey Matheson of Conrad was located in rented facilities at Conrad. To

facilitate husbanding of research in the Triangle Area, Wally Johnson was located at Great Falls from July 1 through October.

Cooperators

1. Farmers and ranchers providing land and equipment during 1975.

Southern Montana
Hoagland Brothers, Broadview
Simon Dreese, Broadview
Dale Schneidt, Molt

Eastern Montana
Duane Arneklev, Antelope
Donald Baue, Fairview
Ed & Bill Lewis, Fairview
Carl Dynneson, Sidney

Central Montana
Larry Barber, Denton
Gerald Barber, Denton
Holzer Brothers, Stanford
Bob Anderson, Geraldine

Triangle Area
Sheridan Erickson, Power
Ed Somerfeld, Power
Ron Bokma, Conrad
Ralph Lindberg & Sons, Conrad
George Rankin, Sunburst
Mac Quinn, Big Sandy

2. Research Centers

Southern Agricultural Research Center providing land and help in conducting frost seeding, no-till and salt garden trials; also use of shop-laboratory facilities.

Eastern Agricultural Research Center providing office space for Toby Panasuk, land and help in conducting numerous trials on the dryland portion of the center.

Central Agricultural Research Center providing land and help with conducting no-till and drill trials; shop-laboratory facilities.

Northern Agricultural Research Center providing help in conducting trials on the Mac Quinn farm.

3. Corporations

Monsanto Chemical Company provided glyphosate used in no-till studies and alfalfa establishment; use of their weed sprayer.

Chevron Chemical Company, Ortho Division provided paraquat used in no-till studies.

Eli Lilly & Company provided Balan used for alfalfa establishment.

Stauffer Chemical Company provided Eptam used for alfalfa establishment.

Cenex of Conrad, Montana provided herbicides and fertilizers used in numerous experiments.

Con-Agra of Great Falls, Montana provided a small quantity of fertilizer.

Northrup King & Company, Billings provided small quantities of various seed stocks.

DeKalb Agricultural Research, Billings provided supply of winter-graze seed.

Equipment

The following equipment was purchased, leased or fabricated in 1975.

Pickup - IHC, 3/4 ton - purchased - Bozeman or Great Falls.
Trailer - Fifth wheel - purchased - Moccasin.
Roto-tillers (3) - 4 H.P.- purchased - Conrad, Sidney, Bozeman.
Generator - 1200 watt - purchased - Bozeman.
Air Compressor - 30 gall., ½ H.P. - purchased - Bozeman.
Vacuum Cleaner - 5 gall. - purchased - Bozeman.
Belt Seeder - Hand pushed - purchased - Conrad.
Tractor - John Deere 2030 - leased for three years - Moccasin.
Spray booms (4) - fabricated - 2 at Bozeman, 1 at Conrad, 1 at Sidney.
No-till drill - fabricated - Huntley or Moccasin
Cone seeders (6) - attachment for no-till drill - Huntley or Moccasin.
No-till drill - fabricated - Using IHC planter units and John Deere coulters - Sidney.
Camera - Nikon 35 mm. - Bozeman

Office Equipment purchased:
IBM Typewriter
IBM Dictating Machines (3)
Hand Calculators (2)
Steelcase Desk
Steelcase Chairs (2)

BUDGET

The following funds were granted through a legislative appropriation to the State Department of Lands.

Expenditures and Appropriations

	Expenditures Jan-June, 1975	Budgeted FY 75-76	Expenditures July-Dec, 1975	% Spent To 1-1-76
Salaries & Benefits	$29,388	$77,144	$39,072	50%
Wages	3,078	4,000	2,879	71%
Travel	4,682	8,700	4,176	48%
Communications	602	500	890	178%
Capital Items	16,639	2,200	--	0
Work Funds, includes maint, utilities, etc.	7,183	14,456	8,834	61%
Total	$61,572	$107,000	$55,851	52%

OTHER SOURCES OF FUNDING

Corporations

1.	Peavey Company, Bismarck, N.D., for use on any aspect of saline seep.	$2,000
2.	Monsanto Chemical Company for no-till studies.	500
3.	Chevron Oil Company, Ortho Division for no-till studies.	1,000
4.	Chevron Oil Company, Ortho Division for saline seep symposium.	350
5.	West-Chem, Billings, for saline seep symposium.	50
	Total Grants	$3,900

In addition to the above, the saline seep program was reimbursed for travel and other miscellaneous expenses incurred in remote sensing through a Tri-state Remote Sensing Project funded by the Old West Regional Commission to South Dakota, North Dakota, and Montana.

Counties

Funds made available for saline seep control by counties, Saline Seep Associations, Soil Conservation Districts, etc.

1. Pondera Saline Seep Association paid for the office and warehouse rental at Conrad since the office was established in June, 1975. They have solicited nearly $2000 for saline seep control programs.

2. Teton County commissioners have allotted $1000 to the Teton Soil Conservation District for saline seep control. They will pay for expenses incurred by the saline seep program for detection and research within their county.

3. Funds were obtained by the West Butte Saline Seep Association Sunburst, to help defray expenses of saline seep detection and research in Toole County. In 1975 they paid for the rental of a fairbooth ($30) at Shelby.

SALINE SEEP STEERING COMMITTEE

In 1974 it was decided that the research and extension program on saline seep at Montana State University would be coordinated by a Saline Seep Steering Committee chaired by the Department Head of the Plant and Soil Science Department. The committee would be made up of eleven members knowledgeable about and involved in some part of the saline seep program and representing both the research and extension functions. The following persons were appointed to the committee: Martin Burris, Oscar Burt, Kurt Feltner, Hayden Ferguson, Glenn Hartman, Mike Jackson, Gene Quenemoen, Jesse Hodgson, Charles Rust, Art Shaw and Chuck Smith. Due to the death of Jesse Hodgson and Chuck Smith's move to North Dakota, the committee now has nine members.

At the time the committee was appointed, it was decided that it would have the following functions:

1)Review all extension and research programs proposed and/or conducted by the Cooperative Extension Service and the Agricultural Experiment Station to assure maximum productivity and coordination with saline seep programs being conducted by other agencies throughout the state.

2)Review program staffing and recommend additional staffing including job descriptions and qualifications required when additional funding becomes available.

3)Recommend distribution of salary and work funds from grant and/or contract funds based on program emphasis between extension and research.

During the past year this committee has provided guidelines for the remote sensing project, the Saline Seep Symposium held in December, 1975, and the coordination of research projects between the saline seep program and the research centers. At the direction of this committee a list of resource personnel involved with some aspect of saline seeps has been compiled.

EXTENSION ACTIVITIES IN THE SALINE SEEP PROGRAM

Practically all of the research projects reported in this report have some saline seep education aspects. Quite extensive experiments were conducted at the Huntley, Moccasin and Sidney Research Centers. These centers have had tours for the general public or advisory groups. Last spring, trials involving seeding, crop adaptability, alfalfa establishment, herbicide application, and no-till studies were conducted on 14 farms in the Triangle Area and Eastern, Southern, and Central Montana. These were extremely important demonstrations in each neighborhood. Late corn for fall grazing planted as a means for using the excessive moisture which occurred last spring was extensively discussed in all neighborhoods where grown. These trials were effective in showing that there were crops, other than wheat and barley, that could be effectively grown in Montana.

In addition to the above demonstrations, the following Extension activities involving both J. L. Krall and Wally Johnson were conducted.

1. Meetings

	No. Held	Kind of Meeting
	13	Public meetings with 10 to 150 in attendance. Presentations given on some aspect of saline seep.
	5	Public meetings with 25 to 200 in attendance. No presentations given.
	10	Association meetings with 10 to 25 in attendance. Many aspects of saline seep were discussed. (All saline seep associations in the state included.)
	1	Saline seep hearing with the Montana legislature.
	8	Advisory council meetings. (Includes Montana State University and State Advisory councils.)
	7	Meetings and field days involving remote sensing or community surveys.
	3	Field tours with groups (up to 50 people) at Moccasin, Broadview and Highwood.
	3	Student seminars at Montana State University.
Total	50	

2. New Releases - Data furnished by the Office of Information, Montana State University, indicates that 35 releases were made since the program was initiated in August, 1974. This includes both Extension and Experiment Station. In addition, several stories were carried by local weekly newspapers in the saline seep areas. There were seven radio interviews and four TV interviews, primarily through the Great Falls station.

3. Publications

Capsule Information Series, a publication of the Montana Agricultural Experiment Station, Montana State University.

Number 6 - Cereal Grains & Peas for Dryland Forage Production and Saline Seep Control by J. L. Krall and A. L. Dubbs.
Number 7 - Warm Season Annual Forages by J. L. Krall

Saline Seep Educational Folders - 400 copies containing sixteen major publications on saline seep assembled at the request of the State CRD Committee for distribution to all state and federal employees.

Major magazine articles published in the Montana Farmer Stockman and in the Montana Collegian. (2)

Fair Displays were set up at Shelby, Great Falls, Fort Benton and Sidney.

4. Slide Series-assisted the Soil Conservation Service in putting together complete series with narration covering all phases of saline seep. Series has been shown in high schools and at small meetings in saline seep affected areas.

5. Saline Seep Control Symposium

A regional Saline Seep Control Symposium was held at Montana State University on December 9, 10, and 11, covering 11 major topics. This program included 24 major papers and 31 participants in seven panel discussions. Registered attendance showed 204 people from ten states and provinces. Proceedings from this Symposium will be published in late February or March.

CLIMATIC CONDITIONS

Weather conditions during 1975 were extremely conducive to saline seep. Precipitation amounts were from 60% to 80% above normal. This was accompanied by cool temperatures which reduced evaporation and increased percolation. During April, May and June, the soils under both fallow and stubble were saturated. Runoff into glacial potholes was increased. These holes which normally retain water on the surface from two hours to two days, held water for weeks. Thus fall sown grain was lost; fallow fields had to be bypassed when fallowing. No doubt water percolated through these holes and through most cultivated soils and added immensely to the underground water.

Amounts of precipitation in 1975 in relation to the normal for a few selected sites in Montana are given in Table 1. Except for Eastern Montana, all locations were well above average from September, 1974 to September, 1975. This is based on available records from the Research Centers in saline seep afflicted areas. Summer precipitation from Weather Service records at Billings, Cutbank and Great Falls show an 82% increase in precipitation from April to November in 1975.

Table 1. Figures showing above average annual precipitation in inches for 1975 for 7 locations across Montana.

Location	Sept.1974-Aug.1975	Normal	Percent of Normal
Sidney*	14.22	13.86	102
Havre*	18.48	11.60	159
Huntley*	16.60	13.14	126
Moccasin*	21.18	15.06	141
	April - Nov., 1975		
Billings	12.79	9.93	129
Cut Bank	21.49	9.65	223
Great Falls	20.30	10.48	194

*Data obtained from Research Center records.

Based on precipitation amounts and soil probe findings, a map of Montana showing areas suitable for recropping was published April 1, 1975, Figure 1. Scattered reports from farm operators indicate that such a map would be helpful in decision making. It is intended to publish a similar probability map this spring with hopes that it would be more extensively used.

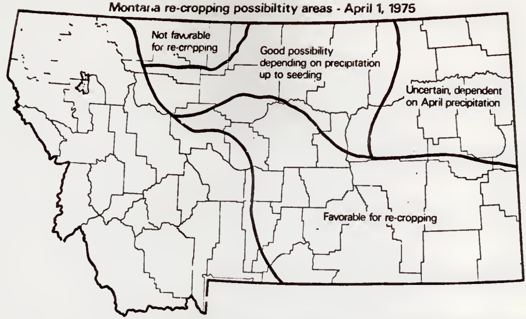

Montana re-cropping possibiltity areas - April 1, 1975
Not favorable for re-cropping
Good possibility depending on precipitation up to seeding
Uncertain, dependent on April precipitation
Favorable for re-cropping

Figure.1. Map of Montana showing areas suitable for recropping as of April 1, 1975.

TITLE: Saline Seep Detection

PROJECT: Plant & Soil Science Department 5009-277
Saline Seep Program 6297-404

YEAR: 1975

LOCATION: Stillwater County, Hailstone Basin, Eastern half of Montana

PERSONNEL: J. L. Krall, Wally Johnson, Harvey Matheson, Saline Seep Program; Charles Egan, County Extension Agent, Stillwater County; Project Leaders.

SUPPORTING AGENCIES: South Dakota Water Resources Institute; Old West Regional Commission; Cooperative Extension Service, Stillwater County; Soil Conservation Service, Stillwater District.

OBJECTIVES:

1. To determine the feasibility of using remote sensing for saline seep detection.
2. To evaluate the neighborhood approach for mapping saline seeps.
3. To test the four-probe method for determining the extent and salinity of a saline seep.

PROCEDURES AND RESULTS:

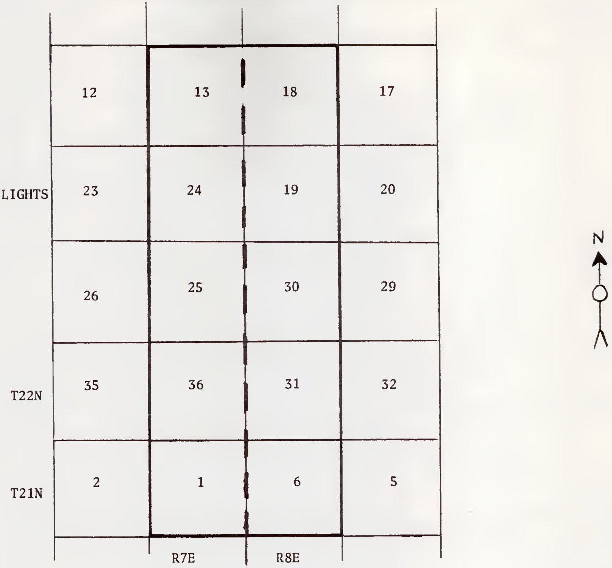
Remote Sensing

The remote sensing project was a three state endeavor under the leadership of the Water Resources Research Institute of South Dakota State University, Brookings. Montana's contribution was primarily to obtain ground truth for two flight lines; (1)Hailstone Basin, north of Rapelje, Montana, and (2) the Highwood Bench. The Hailstone Basin flight was on a line nearly east and west, five miles long, across Sections 25,26,27, 34,35,36, T4N, R20E; Sections 1,2,3, T3N, R20E; Sections 27,28,29,20,31,32,33,34, T4N, R21E; and Sections 3,4,5,6, T3N, R21E. The Highwood Bench flight was on a line north of the town of Highwood, including Sections 13,24,25,36, T22N, R7E; Section 1, T21N, R7E; Sections 18,19,30,31, T22N, R8E; and Section 6, T21N, R8E. See attached map.

The type of ground truth gathered at Hailstone included many aspects. Twenty-five sites were selected with various ground covers and ground truth data was recorded for each site. Soil temperatures were taken at depths of 1 cm., 10 cm., and 50 cm. Temperatures were recorded at flight time at selected sites at 1 cm. and 10 cm. Soil samples were taken of 0-2 cm., 0-20 cm., and at 1 and 2 meter depths. From these samples the percent soil moisture was recorded. The pH reaction was measured on saturated pastes. The electrical conductivity was measured on saturated paste extracts, millimhos/cm. The roughness of the soil surface was determined by laying a meter stick on the surface and measuring the relief. Surface hardness was determined by using a penetrometer. The type of cover at each site was noted and the percent cover was broken down into percent bare ground, percent dead or trash, and percent active vegetation. Surface color and vegetation color were determined using Munsell Color

REMOTE SENSING FLIGHTS IN MONTANA - 1975

HIGHWOOD BENCH
AUG. 26,1975
DAY AND NIGHT FLIGHTS



HAILSTONE BASIN - AUG. 21, 1975 DAY FLIGHT

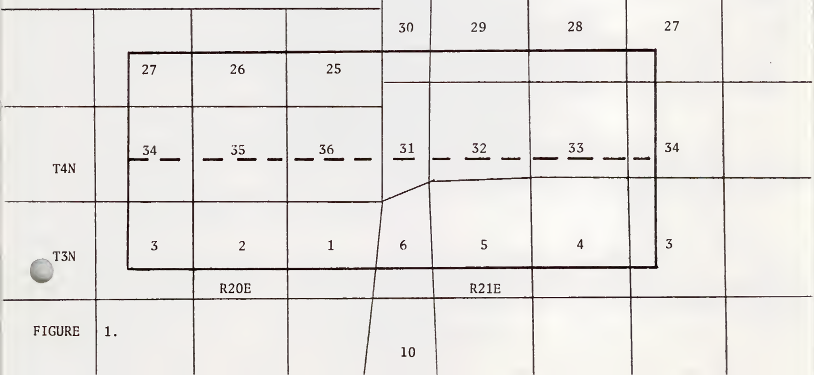


FIGURE 1.

Charts. The percent slope was also estimated. A station was set up over barley to measure total incoming radiation, net radiation, and reflected radiation at 15 minute intervals for 22 hours. At these same intervals, soil temperatures were taken in adjacent stubble using thermocouples at 1 cm., 10 cm., and 50 cm. depths. Ektachrome color and infrared slides were taken of each site. At two sites along the flight line, the atmospheric temperature and relative humidity were recorded. Near the center of the flight line, solar radiation measurements were taken. Soil moisture and density measurements were recorded using a neutron probe device. At selected sites the following were recorded: soil surface temperatures with a radiation themometer, spectro radiation, global radiation, net radiation and albedo radiation.

Neighborhood Approach For Mapping Saline Seeps

The activities regarding this approach to saline seep detection were primarily initiated and conducted by Charles Egan, County Extension Agent, Stillwater County, with offices located at Columbus. He was assisted by Steve Smith, Stillwater District Conservationist, Soil Conservation Service.

To determine the extent of saline seep in Montana, a State CRD subcommittee was organized in 1974 to prepare a questionnaire and conduct a state survey. It was soon found that in order to be meaningful, a questionnaire would have to be relatively complex to ascertain such factors as exact location and size, age of seep, cropping history, probable recharge area, quality of water adjacent to seeps, location of wells, stock water reservoirs and other pertinent factors. It was apparent the individual farm operator would have to be consulted. Two approaches were considered; to question farmers as they visited county ASCS offices or to call farmers together on a neighborhood basis and through use of aerial photos actually designate seeps and other pertinent information. The latter approach was decided on with the northern Stillwater, Yellowstone, Musselshell, and Golden Valley county saline seep areas as a basis for study.

Procedures

Since farmers were to be contacted individually, the questionnaire was simplified to fit the needs. Old aerial photos located in the SCS offices were organized and covered with acetate for mapping. A "dry run" of a neighborhood meeting was held with many researchers and technicians present to rehearse the approach to be taken. Neighborhood meetings involving from 10-20 operators were called at someone's home. A short meeting was held to explain saline seep and procedures to be used for mapping. The agent and district conservationist then sat down with the questionnaires and photos and recorded all the necessary information.

Results

The survey is over 90% completed and out of 112 farms, 101 have been mapped. The information is nearly ready for computer analysis. When completed, the report will give accurate location and size of seeps, as well as other pertinent information. The Saline Seep Program's involvement consisted only of helping develop a questionnaire and outline pertinent necessary information.

The Four Probe Method

The four probe method is a technique to determine saline seep conditions by taking electrical conductivity measurements using a combination electric current source and resistance meter, and four metal electrodes with connecting wires. The electrical resistance is measured across the inner two electrodes while a constant current is passed between the outer two electrodes. The resistance measurements from the meter are then converted to conductivity and given in mmhos/cm. at 25° C.

PROCEDURES:

Three sites were selected as follows: Site 12, 13 and 00 (a site about 1½ miles southwest of the four corners area where a new saline seep was forming). A crosshatch sampling procedure was used and data collected for one and three foot soil depths at 100 foot intervals.

RESULTS AND DISCUSSION:

Almost all readings taken were considered high enough to decrease yield in most crops, Table 1. Soil with a conductivity of 5 mmhos/cm. or larger are considered saline and would produce yield decreases for some crops.

Table 1. Electrical conductivity values for three sites at Hailstone Basin at one and three foot soil depths, Saline Seep Program, Montana State University, July, 1975.

Site 12

Center to North		Center to West		Center to East	
1'	3'	1'	3'	1'	3'
8.4	8.8	8.2	4.8	8.2	9.1
8.3	4.1	14.1	4.4	13.0	3.0
3.6	4.0	4.5	4.1		
8.1	4.1	8.3	3.9		
8.2	4.5	8.3	3.0		
3.8	3.0	3.8	1.1		

Site 13

Center to North		Center to South		Center to East		Center to West	
1'	3'	1'	3'	1'	3'	1'	3'
17.8	5.4	20.1	5.9	20.9	5.4	9.5	5.8
22.3	5.9	3.7	5.4	4.2	5.4	7.2	5.3
17.8	5.9	8.9	5.4	4.1	3.8	3.0	3.5
8.9	5.8	9.3	4.0	3.0	5.4	3.8	4.5
2.6	2.4	1.8	2.4	12.7	5.4	2.0	8.8
2.1	1.4	1.4	1.2	8.3	5.8	1.3	5.5
1.5	1.1	1.2	1.4	4.2	5.4		
1.4	1.1			4.6	5.3		
				7.3	4.0		
				3.9	4.0		

Site 00 (New Seep)

Center to North	
1'	3'
16.9	5.1
20.5	5.0
16.3	5.2
16.3	5.2

As a general rule of thumb, one could say that salinity decreases as you go from what appears to be the center of the seep to the outer edge, as would be expected. Occasionally a low reading will appear near high readings which is unexplainable.

Electrical conductivity is affected by soil moisture and temperature, minerals and metals found in the soil (sodium, magnesium, chlorides) and other factors. The four probe readings can change with any shift of these factors.

SUMMARY:

The four probe method is a quick procedure to determine if saline conditions exist or are a danger. More work needs to be done with the four probe method to determine its accuracy compared to other methods. To give a complete assessment of soil salinity problems in a given area, the four probe method should be used with another method. This may be especially helpful in locating the recharge area.

TITLE: Methods of Recropping Drylands

PROJECT: Saline Seep Program - Plant & Soil Science Department 6297-404; Cooperative Extension Service 6370-001

YEAR: 1975

LOCATION: Southern Agricultural Research Center, Huntley; Central Agricultural Research Center, Moccasin; Agronomy Farm; Statewide farms

PERSONNEL: J. L. Krall, Leader; Don Baldridge, Art Dubbs, Wally Johnson

SUPPORTING AGENCY: Department of State Lands

DURATION: Indefinite

OBJECTIVES:

1. To determine the effectiveness of no-till recropping compared to fallow.
2. To devise a means of reseeding recropped land especially recharge areas.
3. To test various planting mechanisms under various soil and climate conditions.

SCOPE:

Main emphasis is a continutation of studies started in 1973 at Huntley, where winter wheat, spring wheat, barley and corn were planted across winter wheat, spring wheat and barley stubble and fallow after being treated for vegetation control with herbicides and tillage in the fall and spring.

Methods of planting involved slot and open furrow seeding, various types of furrow openers, and packer wheels conducted with barley cropped on barley stubble at Moccasin and Bozeman. In addition, studies were conducted to ascertain the feasibility of recropping under various field conditions in Montana using foliar herbicides in place of tillage.

NO-TILL STUDIES - HUNTLEY

PROCEDURE:

The experimental no-till drill constructed in 1974 and adjusted for slot planting four rows 14 inches apart was used for planting all crops down the various treatments or across the stubble types as illustrated in Figure 1. Varieties used were Cheyenne winter wheat, Centana spring wheat, Unitan barley and Northrup King hybrid corn. The entire area was fertilized with 30 lb/A N. A uniform application of ½ lb/A amine 2,4-D was applied for post emergence weed control. Listed below are treatments used for vegetation control for each crop.

Winter Wheat

1. Glyphosate - preplant - 1 lb/A.
2. Paraquat - preplant - 1 lb/A.
3. Glyphosate - pre-emergence - 1 lb/A - 7 days after planting - coleoptile not emerged - 1-2 cm. long.
4. Tamdem disk early - glyphosate preplant - 1 lb./A.

5. Tillage check - tandem disk after harvest and preplant.
6. Check - No tillage or chemical vegetation control.
7. Tillage as in No. 5, but grain planted with 28 inch row spacing.

Barley
1. Glyphosate - fall - 1 lb/A - no treatment in spring.
2. Paraquat - fall - 1 lb/A - no treatment in spring.
3. Glyphosate - fall and spring pre-emergence - 1 lb/A.
4. Glyphosate - fall - frost seeded March 25 with 2 and 6 row World Collection barley.
5. Tandem disk fall - glyphosate spring - 1 lb/A.
6. Tillage check - tandem disk fall and spring.
7. Check - No tillage or chemical vegetation control.
8. Tillage in No. 6, but grain planted with 28 inch row spacing.

Spring Wheat
1. Glyphosate - fall and spring - preplant - 1 lb/A
2. Tillage check - tandem disk fall and spring.
3. Glyphosate - fall and spring pre-emergence - 1 lb/A.
4. Check - no tillage or vegetation control.

Corn
1. Tandem disk fall - glyphosate spring - 1 lb/A.
2. Glyphosate - spring - preplant - 1 lb/A.
3. Tillage check - tandem disk fall and spring.

Slot vs Open
1. Open - Unitan barley and Centana spring wheat.
2. Slot - Unitan barley and Centana spring wheat.

RESULTS:

A summary of the results for all small grain crops are given in Table 1. The individual plot data is given in Table 2, 3, and 4 for winter wheat, barley and spring wheat, respectively. Data collected for the corn and slot versus open method of seeding are reported in the sections of this annual report dealing with those subjects.

Except for barley no significant differences were found in tillage treatments. With barley, a 6.3 bu/A increase in yield was obtained in favor of no-till. Till plant yields were greater than no-till with winter and spring wheat. Averaging all crops, the yields were the same, 1896 lb/A.

In respect to stubble types, all yields were significantly lower when any of the crops were planted into winter wheat stubble. This yield characteristic was not evident in 1974. Differences in response are attributed to a greater amount of precipitation in 1975 compared to 1974. Thus snow trapping in the taller winter wheat stubble supplied the needed additional moisture in 1974.

Barley and winter wheat planted in 28 inch rows produced the greatest average yield of all the treatments. The yields were considerably higher on fallow than recrop planting in stubble. The 28 inch spacing on fallow was the highest ranking plot for all treatments.

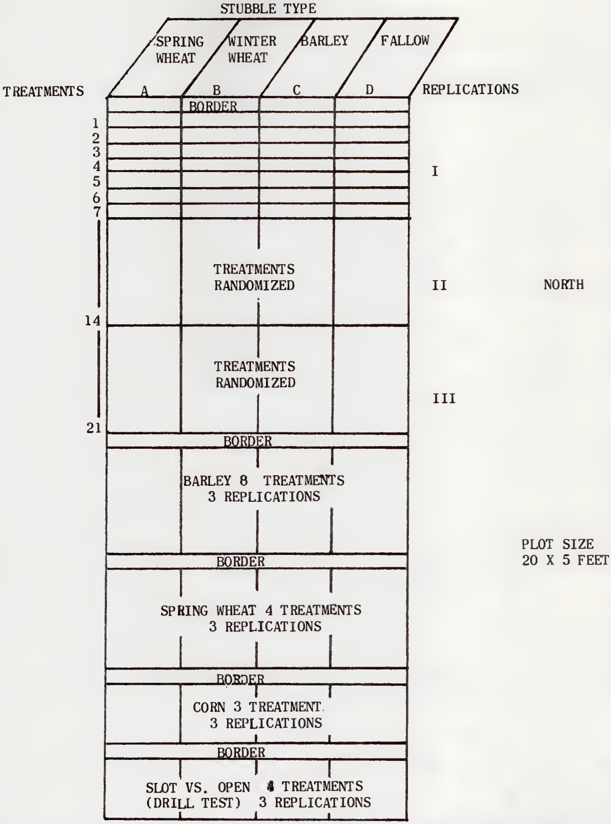


FIGURE 1. PLOT LAYOUT - NO-TILL EXPERIMENT. SOUTHERN AGRICULTURAL RESEARCH CENTER, HUNTLEY, 1975.

Table 1. Pounds per acre of 3 crops obtained from no-till and till plantings into 4 stubble types, Southern Agricultural Research Center, Huntley, Montana, 1975.

CROP	METHOD	STUBBLE TYPES*				
		Sp.Wht	W.Wht	Barley	Fallow	Average
Winter Wheat	No-Till	2320	1992	2783	2425	2380
	Till Plant	2511	1829	2933	2798	2518
				Difference	95%	2.3 bushels
Spring Wheat	No-till	994	595	1364	1464	1104
	Till Plant	1175	754	1540	1609	1269
				Difference	87%	2.8 bushels
Barley	No-till	1856	1440	2789	2727	2203
	Till Plant	1800	1202	2680	1921	1901
				Difference	116%	6.3 bushels
All Crops	No-till					1896
	Till Plant					1896

*Average of 3 replications.

Table 2. Yield in pounds per acre of winter wheat seeded into 3 stubble types and fallow, using 7 different tillage treatments at the Southern Agricultural Research Center, 1975.

WINTER WHEAT NO-TILLAGE
LBS/ACRE

TILLAGE METHOD	REP.	SPRING WHEAT A	WINTER WHEAT B	BARLEY C	FALLOW D	AVERAGE
Treatment 1	I	2306	1993	2517	2076	
Glyphosate	II	2466	2086	2887	2889	
In Fall	III	2189	1897	2945	2310	
1 lb/a	Mean	2320	1992	2783	2425	2380
Treatment 2	I	2357	2094	1691	2283	
Paraquat	II	2291	1856	2974	2349	
In Fall	III	1813	2248	3243	2780	
1 lb/a	Mean	2154	2066	2636	2471	2332
Treatment 3	I	2754	1891	2910	2380	
Glyphosate	II	2197	1915	2867	2187	
Prior to Emerg	III	2476	1893	2801	3181	
1 lb/a	Mean	2476	1900	2859	2582	2454
Treatment 4	I	2696	1615	2984	2314	
DD After Harvest	II	2174	2086	2653	2536	
Glyphosate Pre-	III	1796	1706	2240	2799	
Emerg. 1 lb/a	Mean	2222	1802	2626	2550	2300
Treatment 5	I	2596	1130	3142	2690	
DD After Harvest	II	2378	2328	2563	2988	
DD At Planting	III	2559	2028	3093	2717	
	Mean	2511	1829	2933	2798	2518
Treatment 6	I	2883	1864	3179	1989	
Check	II	2178	1829	3031	2628	
2,4-D	III	2382	2277	3167	2501	
	Mean	2481	1990	3124	2373	2492
Treatment 7	I	2733	2273	2856	3876	
28" Row	II	2474	2172	2809	3224	
Cultivate	III	2174	1917	2343	3327	
Fall & Spring	Mean	2461	2121	2669	3476	2682
Stubble Type Average		2375	1957	2804	2668	

Treatment	DF	MS
Tillage Method	6	20287 N.S.
Stubble	3	295133 **
Method X Stubble	18	14632 N.S.
Error	36	9801

Table 3. Yield in pounds per acre of barley seeded into 3 different stubble types and fallow using 8 different tillage treatments at the Southern Agricultural Research Center, Huntley, 1975.

BARLEY NO-TILLAGE
LBS/ACRE

TILLAGE METHOD	REP	SPRING WHEAT A	WINTER WHEAT B	BARLEY C	FALLOW D	AVERAGE
Treatment 1	I	1842	1434	2665	1582	
Glyphosate	II	1932	1418	2869	2756	
Fall	III	1405	1471	2924	2970	
1 lb/a	Mean	1726	1441	2820	2436	2106
Treatment 2	I	2356	1712	2750	2655	
Paraquat	II	1670	797	2974	2417	
Fall	III	1939	1159	2374	954	
1 lb/a	Mean	1988	1223	2698	2008	1979
Treatment 3	I	2106	1490	2881	2713	
Glyphosate	II	2027	1568	2772	2947	
Fall & Spring	III	1436	1274	2715	2521	
Pre-emergence	Mean	1856	1440	2789	2727	2203
Treatment 4	I	3154	1654	3163	2008	
Glyphosate	II	3144	1642	3356	3313	
Fall	III	2492	1755	2811	3126	
Frost Seed	Mean	2930	1684	3110	2815	2635
Treatment 5	I	1999	775	2992	1880	
Till DD	II	1824	863	2501	2137	
Fall	III	1318	575	2511	2556	
Glyphosate	Mean	1713	738	2668	2191	1828
Treatment 6	I	1842	1196	2996	1872	
Till DD	II	2222	1492	2861	2343	
Fall & Spring	III	1336	917	2182	1547	
	Mean	1800	1202	2680	1921	1900
Treatment 7	I	2368	1463	2935	2672	
Check	II	1716	933	2661	2277	
2,4-D	III	2063	668	2238	2651	
	Mean	2049	1021	2611	2533	2054
Treatment 8	I	3247	2035	3609	3424	
DD Spring	II	3103	1870	3041	3481	
28" Rows	III	2307	1513	2441	4016	
	Mean	2886	1806	3030	3640	2840
Stubble Type Average		2119	1319	2801	2534	

Treatment	DF	MS
Tillage Method	7	15535 *
Stubble Type	3	100304 **
Method X Stubble	21	1898 N.S.
Error	42	999

Table 4. Yield in pounds per acre of spring wheat seeded into 3 stubble types and fallow using 4 different tillage methods at the Southern Agricultural Research Center, Huntley, 1975.

SPRING WHEAT NO-TILLAGE
LBS/ACRE

TILLAGE METHOD	REP	SPRING WHEAT A	WINTER WHEAT B	BARLEY C	FALLOW D	AVERAGE
Treatment 1	I	719	658	1151	1065	
Glyphosate	II	1143	512	1576	1621	
Fall & Spring	III	1120	617	1365	1706	
	Mean	994	595	1364	1464	1104
Treatment 2	I	1028	654	1422	1537	
Double Disc	II	1356	656	1876	1469	
Fall & Spring	III.	1141	954	1323	1821	
	Mean	1175	754	1541	1609	1270
Treatment 3	I	937	397	1099	1562	
Glyphosate	II	1136	508	1531	600	
Pre-emergence	III	1085	892	1147	1552	
	Mean	1053	599	1259	1238	1037
Treatment 4	I	1069	822	236	1527	
Check	II	1219	978	1266	1550	
2,4-D	III	1122	1048	1504	1513	
	Mean	1136	949	1002	1530	1154
Stubble Type Average		1090	724	1291	1460	

Treatment	DF	MS	
Tillage Method	3	11550	N.S.
Stubble	3	120258	*
Methods X Stubble	9	7230	N.S.
Error	18	6540	

METHODS OF PLANTING

PROCEDURE:

By placing a four inch lister shovel between the coulter and the double disk unit planter on the experimental tool bar drill, an open furrow method of seeding was maintained. Removing the shovel created a slot planting method. Comparisons of the two methods of planting were made through three stubble types and fallow at Huntley and at nine locations in Montana. The furrow method opened up a furrow between the 14 inch rows approximately 1½ inches deep and 4 to 5 inches wide. The only soil disturbance occurring from slot planting was from the coulter and double disk planter. The amounts of stubble encountered varied from approximately 1500 to 6000 lb/A.

Drill studies were conducted at Moccasin and Bozeman (Agronomy Farm). All possible combinations of slot vs open furrow, 12 inch shoe, double disk, and three kinds of packer wheels were tested. Due to inclement weather, time only permitted the use of concave and ribbed packer wheels at Moccasin.

RESULTS:

A summary of the average yields obtained from planting barley by the open and slot no-till methods at Huntley are given in Table 5. The individual plot yields are given in Table 6 for both barley and spring wheat. The greatest yield differences were encountered in barley after barley. Table 7 is an average of three spring wheat and six barley plantings using the two methods. On the average the slot method was 2 bushels greater. The individual plot yields for the nine locations are given in Table 8.

Average pounds per acre from the two drill trials are given in Table 9. Due to the wet season, these trials were conducted relatively late in the season. Moisture conditions were wet and it rained soon after each planting; as a consequence the data is of little value. The individual plot data is reported in Tables 10 and 11.

Table 5. Pounds per acre of barley obtained from slot and open no-till plantings, Southern Agricultural Research Center, Huntley, 1975.

	STUBBLE TYPE				
Planting	Sp.Wht	W.Wht	Barley	Fallow	Average
Open	2172	1474	3490	2111	2311
Slot	2071	1233	2414	2128	1961
				Difference	350

Table 6. Yield in pounds per acre of barley and spring wheat planted in the slot and open furrow methods at the Southern Agricultural Research Center, Saline Seep Program, Montana State University; 1975.

SPRING WHEAT & BARLEY SLOT VERSUS OPEN
LBS/ACRE

		STUBBLE TYPES				
TILLAGE METHOD	REP	SPRING WHEAT A	WINTER WHEAT B	BARLEY C	FALLOW D	AVERAGE
Barley						
Slot	I	1650	1114	3481	1167	
	II	2129	1345	3761	2433	
	III	2433	1243	3280	2785	
	Mean	2071	1234	3507	2128	2235
Open	I	2020	1550	3235	1494	
	II	2298	1196	3777	2152	
	III	2199	1675	3459	2686	
	Mean	2172	1474	3490	2111	2312
Spring Wheat						
Slot	I	1665	787	1847	1640	
	II	1533	1007	1734	1700	
	III	878	1019	1829	1689	
	Mean	1359	938	1803	1676	1444
Open	I	1681	682	2135	1722	
	II	1141	799	1843	1270	
	III	793	1153	1587	1480	
	Mean	1205	878	1855	1491	1357

Table 7. Average spring wheat and barley yields obtained from slot vs. open seeding at nine locations in Montana, Saline Seep Program, Montana State University, Bozeman, Montana, 1975.

CROP	OPEN	SLOT
Spring wheat(3)	17.9	19.9
Barley(6)	26.1	28.6

Table 8. Comparison of open furrow vs slot no-till seeding of barley at several locations in Montana, Saline Seep Program, Montana State University, Bozeman, Montana, 1975.

	I	II	III	AVG.
		BARLEY		
SIDNEY				
OPEN	19.4	19.5	21.7	20.2
SLOT	19.3	20.6	18.8	19.7
HUNTLEY				
OPEN	33.7	39.3	37.1	36.7
SLOT	36.3	39.1	35.2	36.9
SCHNEIDT				
OPEN	15.2	21.6	25.0	20.6
SLOT	14.1	31.1	35.1	26.8
ERICKSON				
OPEN	49.2	34.2	30.3	37.9
SLOT	48.8	45.2	33.1	26.8
BOKMA				
OPEN	21.0	27.6	33.9	27.5
SLOT	27.2	36.8	38.2	34.1
MOCCASIN				
OPEN	17.0	13.8	10.5	13.8
SLOT	15.1	10.3	10.4	11.9
		SPRING WHEAT		
ERICKSON				
OPEN	18.9	11.2	10.1	13.4
SLOT	21.3	13.5	12.7	15.8
HUNTLEY				
OPEN	30.8	28.9	30.5	30.2
SLOT	35.6	30.7	26.4	30.9
SCHNEIDT				
OPEN	11.1	8.8	10.9	10.3
SLOT	11.6	12.1	14.9	12.9

Table 9. Yields in lb/A of drill trials using different packer wheels at Central Agricultural Research Center, Moccasin, and Bozeman, Montana, 1975.

MOCCASIN

Drill Type	Shoe & Packer		D.D. & Packer		Average
	Concave	Ribbed	Concave	Ribbed	
Slot	560	609	660	560	597
Open	642	647	720	630	659
	Average Shoe	615	Average D.D.	643	
	Average Concave	646	Avg.Ribbed	612	

BOZEMAN

Drill Type	Shoe & Packer			D.D. & Packer			Average
	Concave	Round	Ribbed	Concave	Round	Ribbed	
Slot	1486	1519	1417	1396	1384	1478	1447
Open	1470	1398	1584	1898	1447	1516	1485
	Average Shoe		1225	Average D.D.		1453	
	Average Concave		1463	Average Ribbed		1409	
	Average Round		1437				

Table 10. Pounds per acre barley obtained from various seeding methods on recropped land, Central Agricultural Research Center, Moccasin, Montana, 1975.

	TREATMENTS			Lb/A				
	Furrow	Opener	Packer	I	II	III	Total	Avg.
1.	Open	Disk	Concave	745	736	685	2166	722
2.	Open	Shoe	Ribbed	1027	514	402	1943	648
3.	Open	Disk	Ribbed	830	762	300	1892	631
4.	Open	Shoe	Concave	663	642	625	1930	643
5.	Slot	Disk	Concave	733	591	659	1983	661
6.	Slot	Shoe	Ribbed	796	522	514	1832	611
7.	Slot	Disk	Ribbed	548	411	425	1384	461
8.	Slot	Shoe	Concave	827	462	394	1683	561

Table 11. Pounds per acre of barley obtained from various seeding methods on recropped land, Saline Seep Program, Montana State University, Bozeman, Montana, 1975.

Treatments			Lb/A					
Furrow	Opener	Packer	I	II	III	IV	Total	Average
Slot	Shoe	Ribbed	1397	1346	1464	1464	5671	1418
Slot	Disk	Ribbed	1551	1269	1448	1644	5912	1478
Slot	Shoe	Concave	1412	1361	1597	1572	5942	1486
Slot	Disk	Concave	1438	1253	1325	1566	5582	1296
Slot	Shoe	Round	1361	1304	1561	1849	6075	1519
Slot	Disk	Round	1382	1115	1505	1536	5538	1385
Slot	Shoe	Pl Concave	1228	1197	1551	1808	5784	1446
Slot	Disk	Cvg Disk	1079	642	1495	1541	4757	1189
Open	Shoe	Ribbed	1299	1479	1741	1818	6337	1584
Open	Disk	Ribbed	1397	1376	1654	1638	6065	1516
Open	Shoe	Concave	1217	1407	1551	1705	5880	1470
Open	Disk	Concave	1202	1690	1397	1705	5994	1499
Open	Shoe	Round	1310	1222	1423	1638	5593	1398
Open	Disk	Round	1305	1371	1469	1644	5789	1447
Open	Shoe	Pl Concave	1459	1356	1140	1808	5763	1441
Open	Disk	Cvg Disk	1387	1536	1376	1541	5840	1460

RECROPPING: FOLIAR vs CONVENTIONAL TILLAGE

PROCEDURE:

To evaluate the effectiveness of chemical foliar applications in lieu of the farmers conventional seed bed preparation, glyphosate and paraquat were applied to large areas (5 to 10 acres) using farm equipment at eight locations in Montana. Out of the eight sites, yield data was available for five. The results are given in Table 12.

Table 12. Bushels per acre obtained from chemical vegetation control compared to conventional tillage at five locations in Montana, Saline Seep Program, Montana State University, 1975.

	TREATMENTS			
Cooperator	Conventional Tillage	Conventional Noble Blade	Chemical Glyphosate	Chemical Paraquat
Duane Arneklev, Antelope	23.5	21.5	21.2	23.1
	Conventional Tillage	Chemical Glyphosate	Chemical Paraquat	
Donald Baue, Fairview	49.7	50.9	44.1	
	No Tillage	Chemical Glyphosate		
Dale Schneidt, Molt	11.1	23.9		
	Varieties	Conventional Tillage	Chemical Glyphosate	Chemical Paraquat
Mac Quinn, Big Sandy,	Spring Wheat	16.6	18.9	18.2
	Barley	30.3	25.8	26.2
	Conventional Tillage	Chemical Glyphosate	Chemical Paraquat	
Ron Bokma Conrad	52.7	52.7	52.7	

Other cooperators were George Rankin, Sunburst; Bob Anderson, Geraldine; and Gerald Barber, Denton. No data was available from these farms due to treatment layout or no data was recorded.

Basing judgement on location where valid comparisons could be made, comparisons between conventional seed bed preparations and no-till chemical vegetation control were nearly alike. Thus it would depend on 1) the cost of chemical per acre in relation to the amount of tillage conducted, and 2) time requirements for spring planting to determine whether or not chemicals were better than cultivation. At Dale Schneidt's where no tillage was conducted, the yields were in favor of chemical vegetation control.

TITLE: Weed Control as Related to Saline Seep

PROJECT: Plant & Soil Science 6297-404

YEAR: 1975

LOCATIONS: Huntley, Conrad, Sidney, Great Falls

PERSONNEL: Wally Johnson, Project Leader; Harvey Matheson and Toby Panasuk, Technicians

COOPERATORS: Ron Bokma, Conrad; Anderson, Hovland at Great Falls; Don Baue, Sidney

SUPPORTING AGENCY: State Department of Lands

DURATION: 2 years, similar work will be carried on in 1976

OBJECTIVES:

1. To determine if herbicides can be used effectively to control weeds in minimum tillage plantings.
2. To observe after-harvest weeds and experiment with different types of nozzles to effectively penetrate the stubble canopy.
3. To determine if lower rates of glyphosate and paraquat are effective in controlling weeds under minimum tillage conditions using additional surfactant.

PROCEDURES:

Glyphosate and paraquat were the two chemicals used in the following investigations. They were used with and without surfactants and at different levels. X-77 was the surfactant used with paraquat and Monsanto's experimental surfactant was used with glyphosate. These chemicals were applied with 20 gallons of water.

Three types of nozzles were evaluated for applying herbicides to standing stubble. The types were a flood jet, a cone spray type and a conventional fan spray type. Fifty pounds of pressure was used to apply herbicides to stubble.

Four rates of glyphosate using different levels of surfactant were evaluated on the following weed species: Kochia (Kochia scoparia), Russian thistle (Salsola kali), pigweed (Amaranthus retroflexus), Canada thistle (Cirsium arvense), and wild buckwheat (Polygonoum convolvulus). Additional surfactant was added to the .75 lb., .5 lb., and .25 lb. rates.

A herbicide trial was conducted on barley at Sidney, Montana to study effectiveness of paraquat with and without surfactant at a rate of .5 lb. per acre. Glyphosate was used at the following rates without additional surfactant: 1 lb. per acre, .5 lb. per acre, and .25 lb. per acre.

Time of application of glyphosate compared to tillage before planting was studied at Huntley, Montana. Winter wheat was planted on spring wheat, winter wheat, barley stubble and on summer fallow. Glyphosate was applied with 20 gallons of water at the rate of 1 lb. per acre.

RESULTS AND DISCUSSION:

Many attempts to penetrate heavy stubble effectively with herbicides, including aerial application, to eradicate after-harvest weeds have failed. A flood jet type nozzle at 55 pounds of pressure appears to penetrate stubble effectively. More investigations must be done in 1976 to get supporting data.

The herbicides which are currently available for weed control in minimum tillage operations are few. Glyphosate and paraquat are two of the better nonresidual, non-selective herbicides to prepare a field for planting.

Glyphosate works well to control annual and perennial weeds as it is a translocated herbicide. Recent investigations show that glyphosate may provide effective foliage control at rates as low as .25 lb. per acre with additional surfactant, Table 1. Kochia was not eradicated by the higher rates of glyphosate. The low rate appeared to be more effective because it was translocated with the higher level of surfactant.

Satisfactory results have been obtained from the use of paraquat to control annual weed species, Table 2. It will not kill volunteer winter wheat when applied in the spring. Barley yielded 42.7 bu/a when paraquat was applied at .5 lbs. per acre preplant at Sidney, Montana. Glyphosate applications were somewhat less effective as was paraquat without surfactant.

When glyphosate was applied preplant and post-plant over three stubble types and summer fallow, there were no significant differences compared to the till plant, Table 3. It is risky to apply glyphosate after planting because you may be delayed because of the weather conditions. The post-plant treatment may be more effective under conditions where severe weed infestations exist. Herbicides may be as effective as tillage in many instances.

SUMMARY:

Glyphosate can be used effectively to control annual and perennial weeds in minimum tillage systems. It is expensive at the present time and more investigation should be done using the lower rates to determine if they are as effective as higher rates.

Paraquat works well to control annual weeds in minimum tillage systems but also is expensive at the present recommended rates.

Chemicals, when applied at the proper rate and time, can be as effective as tillage in controlling weeds.

Table 1. Foliage control study conducted on four weed species at Conrad, Montana, using different rates of glyphosate, Saline Seep Program, Montana State University, 1975.

	PERCENT FOLIAGE CONTROL			
	*Glyphosate Lbs/A			
WEED SPECIES	1#	.75#	.5#	.25#
Kochia	70%	70%	70%	80%
Common Pigweed	90%	90%	90%	90%
Canadian Thistle	80%	80%	80%	80%
Wild Buckwheat	70%	65%	70%	80%

*Additional surfactant used on .75, .5, .25 lb. rates. Readings taken 60 days after chemical application.

Table 2. Herbicide trial conducted at Sidney, Montana, using paraquat and glyphosate as preplant treatments on barley, Saline Seep Program, Montana State University, 1975.

Treatment	Rate	Barley Bu/Acre
Paraquat	½ lb/a + surfactant	42.7
Paraquat	½ lb/a	34.4
Glyphosate	1 lb/a	34.4
Glyphosate	.5 lb/a	40.1
Glyphosate	.25 lb/a	34.8

Table 3. Compares time of application of glyphosate over three stubble types and fallow vs tillage before planting at Huntley, Montana, Saline Seep Program, Montana State University, 1975.

	Lbs/A Winter Wheat				
Treatment	Stubble Type				
	Spg.Wht	Wtr.Wht	Barley	Fallow	Avg.
Pre-plant	2320	1992	2783	2425	2380 N.S.
Pre-emerg	2476	1899	2859	2582	2454 N.S.
Till-plant	2511	1829	2933	2798	2518 N.S.
			P.P. 95%	P.E. 97%	

TITLE: Frost Seeding Small Grains on Dryland

PROJECT: 6297-404

YEAR: 1975

LOCATION:

PERSONNEL: J. L. Krall, Leader; Don Baldridge

OBJECTIVES: To determine if small grains can be sown while the ground is frozen or during the latter part of February or in March to extend the time for seeding recropped and saline seeped land.

PROCEDURE:

Using the standard plot technique, five standard barley varieties, three genetic selections of barley, and three isogenic lines of Centana spring wheat, were planted on fallow March 25 with the no-till experimental drill in 14" spacing. For comparison, three standard varieties and two genetic selections of barley and two varieties of spring wheat were planted adjacent to the frost seeded grains on May 5.

Another comparison was made in the large no-till study with barley. Treatment 4 was frost seeded on March 25 across four stubble types and fallow. This planting allowed for a comparison of no-till frost seeding versus normal methods.

RESULTS:

The pounds per acre obtained from the frost seeding of barley and spring wheat are given in Table 1; the normal date in Table 2. The results of no-till frost seeding across various types of stubble is given in Table 3. A summary of the findings is given in Tables 4, 5, and 6. Differences as great as 53.8 bu/A of barley were obtained in favor of frost seeding on fallowed land. The two and six row genetic selection did not yield as well as the standard varieties. Barley frost seeded into spring wheat stubble gave a greater increase than into winter wheat or barley stubble or on fallow. An eleven bushel increase was obtained irregardless of previous cropping. Frost seeded Centana spring wheat yielded 6.8 bushels more than normal seeding.

SUMMARY:

Frost seeding of spring grains looks promising. No failures with barley have been obtained at Huntley in the past nine years. Its' success in chinook belts is not known. This method of planting needs to be tried next to saline seeps that are generally too wet to plant after the ground has thawed. It appears more promising for no-till recropping than for fallow. Past weather patterns show that there is ample time each spring for frost seeding, thus the seeding period could be lengthened.

Publication: Krall, J. L. Some Recent Innovations to Facilitate Recropping. Montana State University, Cooperative Extension Publication; in press.

Table 1. Pounds per acre obtained from frost seeding 8 varieties of barley and 3 varieties of spring wheat on March 25, 1975. Southern Agricultural Research Center, Huntley, Montana.

Barley	Rep I	Rep II	Rep III	Average
Steptoe	4480	5971	4253	4901
Galt	3477	5192	3274	3980
Erbet	4280	4801	2926	4002
Compana	3962	4242	3713	3972
Unitan	5014	5294	5022	5110
Dryland Comp.	3422	3606	3477	3502
6 Row Comp.	3483	4674	2630	3596
2 Row Comp.	2721	3765	2187	3891
Spring Wheat				
Centana Tall	1474	1474	1406	1451
Centana Med.	1639	1811	2126	1859
Centana Short	1321	1726	658	1235

Table 2. Pounds per acre obtained from normal seeding of 5 varieties of barley and 2 varieties of spring wheat on May 5, 1975. Southern Agricultural Research Center, Huntley, Montana.

Barley	Rep I	Rep II	Rep III	Rep IV	Average
Steptoe	2349	2282	2320	2320	2318
Erbet	1637	1402	1438	1002	1370
Compana	2045	2567	2239	2028	2220
6 Row Comp.	1282	1541	1484	1191	1375
2 Row Comp.	585	758	849	348	635
Spring Wheat					
Centana	1165	1076	1273	909	1106
Norana	1206	959	882	947	999

Table 3. Pounds per acre obtained from frost and normal seeding of Unitan barley in no-till studies, Southern Agricultural Research Center, Huntley, Montana, 1975.

		Stubble Type				
Treatment	Rep	SpWht	W Wht	Barley	Fallow	Average
Normal	I	1842	1434	2665	1582	
Seeding time	II	1932	1418	2869	2756	
Glyphosate	III	1405	1471	2924	2970	
Fall	X	1726	1441	2820	2436	2106
Frost	I	3154	1654	3163	2008	
Seeding	II	3144	1642	3356	3313	
Glyphosate	III	2492	1755	2811	3126	
Fall	X	2930	1684	3110	2815	2635

Table 4. Average Bu/a obtained from frost and normal seeding barley (March 25-May 5 respectively) on fallowed dryland, Southern Agricultural Research Center, Huntley, Montana, 1975.

Variety	Frost	Normal	Difference
Steptoe	102.1	48.3	53.8
Erbet	83.4	28.5	54.9
Compana	82.8	46.2	36.6
2 Row Sel.	60.2	13.2	47.0
6 Row Sel.	74.9	28.6	46.3

Table 5. Bu/a obtained from frost vs. normal seeding of recropped barley grown on various types of stubble, Southern Agricultural Research Center, Huntley, Montana, 1975.

		Bu/Acre			
Date	Sp.Wht	W.Wht	Barley	Fallow	Average
March 25	61.0	35.1	64.8	58.7	54.9
May 5	36.0	30.0	58.7	50.7	43.9
Difference	25.0	5.1	6.1	8.0	11.0

Note: Average of 3 replications, 2 and 6 row selections and Unitan, respectively.

Table 6. Bu/a obtained from frost and normal seeding of spring wheat on fallow, Southern Agricultural Research Center, Huntley, Montana, 1975.

		Bu/Acre	
	Frost	Normal	Difference
Centana	25.2	18.4	6.8

TITLE: Evaluation and Development of Economic Crops for Recharge and Discharge Areas

PROJECT: Plant & Soil Science Department 6297-404

YEAR: 1975

LOCATIONS: Conrad, Power, Sunburst, Stanford, Molt, Southern Agricultural Research Center, Huntley, Eastern Agricultural Research Center, Sidney

PERSONNEL: Wally Johnson, Leader; Toby Panasuk and Harvey Matheson, Technicians

COOPERATORS: Joe Krall, Sunburst; Ron Bokma, Conrad; Ed Sommerfeld, Power; Holzer Brothers, Stanford; Dale Schneidt, Molt; and Donald Baue, Fairview.

SUPPORTING AGENCY: State Department of Lands

DURATION: 1974-77

OBJECTIVES:

1. To establish a salt garden at Southern Agricultural Research Center, Huntley, Montana, to test the salt tolerance of various plants.
2. To plant various species of annual plants on saline seeps for selection of salt tolerant types.
3. Screen species suitable for extracting water from the recharge areas.
4. To plant corn on summer fallow strips to prevent excess moisture from filtering through the soil profile and contributing to saline seeps.

PROCEDURES:

NaCl was applied to 13 levels of salt concentration in the salt garden established at the Southern Agricultural Research Center at Huntley in 1967 in an effort to bring the levels up to the desired salinity. This salt garden was devised as a means for crop salt tolerance testing as the levels of salt increased at 10 foot increments from 2 mmohs/cm to 15 mmohs/cm. In 1975 three replications of the World Collection of barley and spring wheat were planted for salt tolerant selections across the plots with the intent of harvesting seed at the level, if survival associated with the highest salt concentration. In addition, fourwing saltbush, kochia, and other crops were planted for tolerance.

Six sites were selected to grow annual species for salt tolerance and ability to lower the water table on recharge areas. These species were planted in three replications. Table 1 shows those types of plants that were planted on discharge and recharge areas. Plantings were started near the middle of seeps on out to normal soils to obtain a graduated effect.

Dryland corn was planted at Sidney, Huntley, Power, Conrad, and Stanford at various row spacings. The plantings were made in late June and early July with regular grain drills. An attempt was made to establish two plants per square foot. All corn plantings were sampled for yield before the first frost in 1975. Spring grains will be planted into the corn stubble in 1976.

Seven different crops were evaluated on fallow and recropped dryland at the Eastern Agricultural Research Center at Sidney and the Don Baue farm at Fairview in 1975. These crops were planted in three replications and yields and proteins were calculated. See Table 4 for crops planted.

RESULTS AND DISCUSSION:

Attempts to recharge the salt garden at Huntley were a failure. Evidently the greater than normal precipitation leached all of the salts below the root zone. No delineation could be detected between salt levels of the barley, wheat or other crops. As a result the test was abandoned. Plant selection for salt tolerance using the technique of planting from extremely salty soils near the middle of a seep on out to the normal soils appears more promising as salinity is constantly maintained. However, annual concentrations have to be obtained. Due to the lack of salt differences none of the crops planted on the salt garden were harvested.

Various plants were seeded or transplanted at saline seep sites around the state of Montana. Table 1 shows how well various plants performed. There was little difference among the barley or wheats, with barley being the most salt tolerant of the two. Wintergraze was quite salt tolerant, as was altai wildrye,fourwing saltbush, and strawberry clover. Legumes generally were not salt tolerant.

Establishment of species on saline seeps is the number one problem. These sites are too wet in the spring to seed and soon become dry or too salty to establish plants. Many species did well until the end of July when a severe moisture stress killed many of the species. Fourwing saltbush and altai wildrye look promising as perennial species for salty areas.

Fababeans appear to have some potential as an economic crop for recharge areas. They are a deep rooted annual legume and may put 30 to 40 pounds per acre of nitrogen back into the soil annually. These beans are high in Lysine and yields averaged 1400 lbs/a of dry beans, Table 2. Dryland yields from Sidney and irrigated yields from Huntley were obtained. They were also planted at Moccasin but an insect infestation (blister beetle) at flowering reduced yields to zero. The infestations were not as bad in other areas although some reduction in yield was noted. Under irrigation, the beans flower for long periods of time which makes them difficult to harvest. Since 1975 was an extremely wet year, the beans did well on dryland which may not be true of other years. More investigations into annual legumes will be continued in 1976.

Fourwing saltbush is a deep rooted perennial, sub-shrub that is quite palatable to livestock and wildlife. Root depths may extend to 15 meters depending on underlying soil formations. Saltbush belongs to the genus Atriplex of which many are faculative halophytes and achieve salt tolerance by accumulations against a concentration gradient and then partioning those ions in specific cells. Even though most crop plants cannot tolerate salt concentrations exceeding a few hundred parts per million, many halophytes can cope with concentrations exceeding that of sea water which is about 25,000 ppm.

The corn plantings made on summer fallow strips yielded well. There were problems getting regular field corn seed to feed evenly through the grain drill. Corn yields ranged from 1.3 tons of dry matter/a to 4.5 tons, Table 3. An addition of 300 lbs. of 34-0-0 per acre at Power increased yields from 1.3 to 2.9 tons per acre.

Spring grains will be planted on these corn strips in the spring of 1976 with an experimental no-till drill and a conventional lister type grain drill used by farmers.

Seven crops were evaluated for recropping in eastern Montana. There were numerous differences between the yield of crops grown at the Baue farm at Fairview and those from the Research Center at Sidney, Table 4. Yields were considerably higher at the Baue farm which could be attributed to moisture and fertility levels. Safflower was the only crop that produced equitable yields on recropped land at the Research Center. All crops produced yields comparable to those on fallow at the Baue farm. Safflower and corn did especially well under recropped conditions at that location.

SUMMARY:

The idea of using a salt garden to select salt tolerant crops has been abandoned in favor of using natural saline seep sites.

Few species exhibit salt tolerance that would be of economical use. Several species that look promising are fourwing saltbush, altai wildrye, and wintergraze. Most legumes do not exhibit salt tolerance. Probable new crops for recharge areas would include fababeans, winter peas and safflower in areas that would permit maturity, and fourwing saltbush.

Corn will provide excellent grazing for cattle and will use up some of the excess moisture in fallow strips on years with above average precipitation. We recommend that farmers use "rounds" when planting corn with a grain drill.

Crops will again be evaluated for effectiveness on recropped land as the past year was an unusual one in respect to precipitation.

Table 1. Salt tolerance ratings* of plants established on saline seeps at various locations in Montana, Saline Seep Program, Montana State University, 1975.

Plant	Mmhos/cm Low (0-7)	Medium (7-14)	High (14-20)
Steptoe barley		X	
Hoaglund salt barley		X	
Huntley salt barley		X	
Dryland Comp. W. Coll. barley		X	
Erbet barley		X	
Era spring wheat	X		
W. Coll. spring wheat	X		
Wintergraze			X
Safflower		X	
Austrian winter peas	X		
Lentils	X		
Fababeans	X		
Kochia			X
Fourwing saltbush			X
Onions		X	
Altai wildrye			X
Strawberry clover		X	
Forage radish		X	
Sorghum x sudan	X		

*These ratings do not imply the plant will produce economic yields.

Table 2. Lbs/a and % protein of six fababean varieties*on dryland at Sidney, Montana, Saline Seep Program, Montana State University, 1975.

Variety	Yield-Lbs/A	% Protein
Rinal	1414	26.68
Foec nevyje	1267	26.45
Ackerperle	1596	27.26
Robinson	1548	26.22
Maxime	1387	27.72
Blue rock	1284	27.95
Average	1416	27.05

*No significant difference among varieties for yield or protein.

Table 3. Tons per acre dry matter, row spacings, plant population per acre at six sites in Montana of dryland corn, Saline Seep Program, Montana State University, 1975.

Location		D.M., T/a	Row Spacing	Plant Pop./A
Conrad		3.8	10"	33,588
Power	Non-fert.	1.3	28"	14,457
	Fert.*	2.9	28"	14,082
Stanford		1.1	28"	27,600
Huntley		.9	28"	Not available
Sidney		4.2	14"	Not available
Fairview		4.5	14"	Not available

*Fertilized with 300 lbs. 34-0-0/A.

Table 4. Species variety yield trial comparing fallow vs recrop yields in pounds per acre at the Eastern Agricultural Research Center at Sidney and the Don Baue Farm at Fairview, Mt. in 1975.

SPECIES VARIETY YIELD TRIAL - LBS/ACRE

Crops	Methods	Research Center I	Research Center II	Research Center III	Research Center AVG.	Baue Farm I	Baue Farm II	Baue Farm III	Baue Farm AVG.
Corn	Fallow	42660	38154	44882	41899	42580	41560	52460	45533
	Recrop	21702	28042	18630	22791	43240	47220	40780	43747
Spring Wheat	Fallow	2356	2386	2812	2518	2634	2882	2871	2796
	Recrop	1245	1146	1173	1188	1356	2266	2159	1927
Durum	Fallow	2700	2401	2396	2499	2415	2958	3369	2914
	Recrop	1646	1444	1329	1473	2743	2071	2451	2422
Safflower	Fallow	1118	1336	2085	1513	211	67	99	126
	Recrop	800	797	1370	989	297	458	349	368
Barley	Fallow	3370	3519	3880	3580	3816	4045	3446	3769
	Recrop	1685	1767	1988	1813	2492	2105	2493	2363
Peas	Fallow	1093	1152	1867	1371	1959	1833	2064	1952
	Recrop	731	510	493	578	1803	1207	2320	1777
Peas & Oats	Fallow	17470	18926	17907	18101	16888	28915	29700	24168
	Recrop	16160	7571	7425	10385	22362	20382	24022	22255

Analysis of Variance:

Treatment	Research Center DF	Research Center MS	Research Center F	Baue Farm DF	Baue Farm MS	Baue Farm F
Crops	6	828586	116 **	6	1686700	1993 **
Fallow vs Recrop	1	223036	31 **	1	8773	1.04 N.S.
Crops X Method	6	70693	9.9 *	6	1015	.119 N.S.
Error	12	7148		12	8462	

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TITLE: Soil Fertility as Related to Saline Seeps

PROJECT: Plant & Soil Science 6297-404

YEAR: 1975

LOCATIONS: Conrad and Geraldine, Montana

PERSONNEL: Wally Johnson and J. L. Krall, Project Leaders; Toby Panasuk and Harvey Matheson, Research Technicians

COOPERATORS: Ron Bokma, Conrad; Sheridan Erickson, Power; Robert Anderson, Geraldine; Donald Baue, Fairview

SUPPORTING AGENCY: State Department of Lands

DURATION: 1974-77

OBJECTIVES:

1. To determine the effectiveness of fertilizers for recropping.
2. To determine the effect of nitrogen fertilization on the protein content, nitrate accumulation and forage yield on kochia.
3. To determine if Austrian winter peas and fababeans will produce sufficient amounts of nitrogen in short term crop rotations.

PROCEDURES:

Seven farms for recropped versus fallow yields were sampled in 1975 and in most cases, fertility rates were similar for fallow and recropped land. One square foot of row at ten random places was sampled throughout the field. Yield using number of heads per square foot, seeds per head and weight in grains for an average number of seeds per head were calculated.

A site was selected at Conrad to fertilize kochia using four rates of nitrogen; the rates of nitrogen used were 0, 20, 40, and 80 lb/a respectively. These treatments were replicated three times at random using an untreated plot as a check. The plots were to be harvested twice, at pre-bloom and post-bloom. Forage yields were calculated by taking three foot square samples from which percent nitrates and protein were determined.

Austrian winter peas and fababeans were planted at Conrad, Power, Geraldine, and Sidney to determine the amount of residual nitrogen put back into the soil. These areas were sampled to a depth of 6 inches before planting peas or beans and then sampled again this fall to a 6 inch depth to determine nitrogen content.

RESULTS & DISCUSSION:

Yields from seven farms were calculated comparing fallow versus recropped land, Table 1. Averaging the yields showed that recropped yields were 75% of fallow yields. The same amount of fertilizer was applied to both cropping regimes in all cases. This indicates that on years when there is excess precipitation, recropped land should be fertilized at higher rates to get comparable yields.

Table 1. A comparison of yields on recropped versus fallowed winter wheat at seven different locations in North Central Montana, Saline Seep Program, Montana State University, 1975.

	Yield Bu/a		
Farm & Location	Recropped	Fallow	%
Bowman - Belt	2691	2939	91
Grossman - Highwood	4363	3104	140
Dahl - Highwood	1482	3585	41
Skarda - Denton	2002	3078	65
Bitz - Big Sandy	3031	2569	118
Ernst - Stanford	1574	2554	61
Davidson - Highwood	5808	5993	96
Average	2461	3275	75

Kochia responded well to applications of nitrogen, Table 2. Kochia yields with no fertilizer compared to those yields at 40 to 80 lb/a of nitrogen were significantly different. However, kochia will accumulate large quantities of nitrates. The tolerance level is .3%. Any level greater than that is potentially harmful to livestock. Kochia has protein percentages comparable to alfalfa at some stages of growth. If kochia is to be used as a forage, it would have to be mixed with other forages to dilute the nitrate percentage.

Samples of kochia taken at the mature stage of growth showed low percentages of nitrates, Table 3. Proteins also dropped as would be expected with maturity.

Table 2. Yield response, percent nitrate levels and percent protein of kochia at three levels of nitrogen fertilization at Conrad, Montana, Saline Seep Program, Montana State University, 1975.

Treatment (N lb/a)	Yield (T/a)	% Protein	% Nitrates
0	1.5	14.5	.3
20	5.5	10.2	.5
40	6.3	15.3	1.1
80	9.3	17.2	4.7

Note: Kochia harvested at pre-bloom stage.

Table 3. Percent protein and percent nitrates of kochia at three levels of nitrogen fertilization harvested at post-bloom at Conrad, Montana, Saline Seep Program, Montana State University, 1975.

Treatment (N lb/a)	% Nitrates	% Protein
0	.2	9.6
20	.24	9.1
40	.3	9.0
80	.48	7.6

Soil samples were taken at Conrad, Power, Sidney and Geraldine to calculate how much residual nitrogen was produced by Austrian winter peas. Results have been erratic, Table 4. More investigation needs to be done

to determine if winter peas will produce a significant and economic amount of nitrogen. Primary results on fababeans show that the beans may produce 40 to 50 pounds of nitrogen but results were erratic.

Table 4. Pounds of residual nitrogen in top 12 inches of soil per acre by Austrian winter peas at four locations, Saline Seep Program, Montana State University, 1975.

Locations	Lbs. Residual N
Power	20
Conrad	15
Geraldine	35
Sidney	10
	Avg. 20

SUMMARY:

The ferility trials on kochia will be duplicated during 1976 to get further information concerning nitrates and yield responses of kochia to nitrates.

Austrian winter peas will be planted at several locations in 1976 so information may be obtained on how much nitrogen they leave in the soil. Weed control problems with winter peas will also be studied.

Fababeans appear to have some promise as a crop for recharge areas but seed will have to be increased in 1976 to continue studies on this species.

The accuracy of sampling techniques will be further investigated as we monitor recropped fields for comparison to fallowed land. There is some difficulty in finding fallow yields for comparison in some areas.

TITLE: Use of Herbicides to Establish Dryland Alfalfa

PROJECT: Plant & Soil Science 6297-404

YEAR: 1975

LOCATION: Power and Stanford, Montana

PERSONNEL: Wally Johnson, Project Leader; Harvey Matheson, Research Technician

COOPERATORS: Sheridan Erickson, Power; Holzer Brothers, Stanford, Montana

SUPPORTING AGENCY: Department of State Lands

DURATION: 1975-77

OBJECTIVES:

1. To determine if pre-emergence and post-establishment herbicides would aid in the establishment of dryland alfalfa and if there were significant increases in yield results from these practices.
2. To determine if adequate stands could be obtained using grain drills with lister shovels and packer wheels.

PROCEDURES:

Chemicals used were Eptam, 1.5 lb/A; Balan, 1.5 lb/A; a mixture of Eptam, .75 lb/A and Balan, .75 lb/A and 1 pound of glyphosate; applied preplant. The Eptam and Balan treatments were incorporated into the soil at a depth of 2 to 3 inches with a rotary tiller at Power, and with two harrowing operations at 90° angles at Stanford. All chemicals were applied with 20 gallons of water. These treatments were replicated three times at random.

Sencor and Kerb W-50 will be applied in the spring of 1976 at recommended rates. Conventional shovel type grain drills were used with packer wheels.

RESULTS & DISCUSSION

Satisfactory weed control was obtained at Power for all treatments for about six weeks except where glyphosate was used as it only controls existing vegetation. The weed species present at Power were kochia (Kochia scoparia), Russian thistle (Salsola kali), and wild oats (Avena fatua).

Weed control was poor at Stanford because it was extremely dry when the chemicals were applied and incorporation with harrows is not sufficient. A severe infestation of wild oats was observed at Stanford. No yield data was obtained at either site during the establishment year but forage yields will be calculated for the various treatments in 1976.

Conventional grain drills found in dryland farming operations can be used successfully to plant alfalfa if the drill has packer wheels attached to it. The seed bed may not be firm enough if packer wheels are not used and you would risk the chance of placing the seed too deep to get good emergence.

SUMMARY:

Chemical weed control for dryland alfalfa is costly and pre-emergence treatments may be erratic because of incorporation procedures and moisture. Most pre-emergence chemicals must be incorporated into the soil which is a disadvantage. To establish alfalfa successfully on dryland, the following procedures should be followed:

1. Plant as early as possible to insure an adequate moisture supply.
2. Prepare a firm seedbed or use packer wheels on the drill.
3. Plant about 5 pounds of P.L.S. per acre with 25 pounds of phosphorus per acre with a regular grain drill (double disk or lister type).
4. Swath the planting when the plants reach a heigth of 6 to 8 inches to reduce competition from weeds.
5. Cheatgrass and other grassy weeds may be controlled in established stand by applying Kerb-W-50 or Chem-hoe.

More investigational work on establishing dryland alfalfa will be carried on in 1976.